



Utah Transit Authority Light Rail Design Criteria

Chapter 1 General Requirements

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 1 GENERAL REQUIREMENTS

1.1 Purpose

The material contained in the following chapters provides a uniform basis for project design of light rail transit (LRT) systems.

These criteria serve as guidelines and do not substitute for engineering judgment and sound engineering practice. Exceptions may apply in special cases. Applications for exceptions to the criteria, deviation from the criteria, changes to the criteria, additions to the criteria, and other questions should be submitted in writing to the UTA Light Rail Transit Project Director and must be approved in writing before the modification is implemented.

1.2 Project Goals

The basic goal of the project is to provide an improved public transportation system in a cost-effective, environmentally sensitive and socially responsible manner. Design of project elements will be based on a “design to cost” philosophy.

1.2.1 Proven Hardware

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

Specifications for the LRT system shall be prepared in such a way as to encourage competitive bidding by established manufacturers of transportation equipment in accordance with current federal procurement guidelines.

1.2.2 Design Life

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

Major system equipment shall also be designed for a minimum of 30 years before complete replacement becomes necessary, assuming that approved maintenance policies are followed.

1.2.3 Service Integration

The LRT system shall be designed as an integral part of the overall UTA transportation system. Design considerations shall be made for the efficient interchange of passengers to and from private and other public transportation modes.

1.2.4 Design to Cost

This project uses the philosophy of budget-limited design. Each major element of the system shall be designed not to exceed the construction budgets established for the project. All systems identified in this document shall meet the criteria established herein and not exceed the project capital costs with appropriate escalation to year and month of construction.

1.2.5 System Safety

Safety shall be the overriding policy in all aspects of light rail system design and operations. All light rail vehicles, equipment, and facilities shall be designed in accordance with all relevant codes and standards and maintained to ensure safe operation. All employees will take every reasonable precaution to avoid injury to themselves and others.

Safety to the system's operators, patrons, and the general public shall be implemented by:

- Appropriate design of light rail vehicles (braking rates, use of fire retardant materials, etc.)
- Appropriate design of the wayside facilities (lighting of platforms, signals, etc.)
- Defining and adopting a System Safety Plan

The items listed above are incorporated in the technical sections of this Design Criteria Manual. They will also be included in the detailed specifications that will be prepared for the construction and procurement of physical systems.

The primary safety goal of the light rail system is to achieve the highest practical level of safety while maintaining operational and cost effectiveness.

1.2.6 Baseline LRT System

- Ballasted track (ballast with curbing for in-street and ballast on fill for non-in-street) with concrete tie, continuously welded 115 RE rail, on top of existing sub-grade
- Standard H-beam OCS poles in corridor, and standard galvanized round poles on stations and on 90 degree turns
- Full depth high profile overhead catenary system
- Center loading, basic suburban LRT station platform (similar features as the 3300 South station)
- Non-landscaped park-and-ride facilities to serve the stations and per local jurisdictional criteria
- Existing utilities protected in place where facility is not in conflict
- At-grade LRT system resulting in safe, yet cost-effective "bare bones, no frills" philosophy
- LRT corridor minimizing right-of-way and environmental impacts

1.3 System Description

The design criteria in the following chapters apply to all UTA light rail projects. All system elements will be designed to meet the requirements of the Americans with Disabilities Act (ADA).

1.3.1 Stations

Stations shall be either low-center or low-side loading platforms. ADA requirements will be met through the use of ramps and mini-high block platforms.

1.3.2 Track

Double track will be used. The typical configuration should allow for 10-minute headways during peak hours, 15-minute headways during off-peak hours, and 30-minute headways during evening hours. The designs shall use 115 RE rail, minimum.

1.3.3 Speed

The track alignment civil design speed in exclusive right-of-way shall be the maximum vehicle speed plus 10 mph where the right-of-way and physical constraints permit. Superelevation shall be designed to match the anticipated LRT running speed of each section of track. In the street-running sections, the design speed will match the posted street traffic speed plus 10 mph, except as directed in MUTCD.

1.3.4 Structures

Existing bridges and culverts shall be retrofitted or repaired as necessary to carry the light rail loads and to meet seismic requirements.

1.3.5 Vehicles

The light rail vehicle shall use a nominal 750 Vdc and be of proven technology. Vehicles may be new or used depending on the cost and timing of the procurement.

1.3.6 Yard and Shop

The yard and shop shall provide standard maintenance and operations services for the LRV fleet.

1.3.7 Overhead Contact System (OCS)

In sensitive areas an aesthetically pleasing low-profile catenary OCS shall be provided. A simple catenary auto-tensioned system shall be used for the mainline and yard lead tracks, and a single-wire fixed termination configuration shall be used in the yard and shop areas.

1.3.8 Signal/Traction Power

Signaling shall be wayside, block signalization with interlocks. The traction power shall be supplied by 1.5-megawatt substations located at approximately 1-mile intervals. Coordinate the location and size of signal/traction power equipment with UTA.

1.3.9 Weather Conditions Criteria for Systems Design

Systems equipment including vehicles, electric traction supply and distribution system, signal system, and fare collection equipment shall be capable of maintaining operation within the climatic conditions of the Salt Lake City area. The following data are to be used as the design weather conditions:

Temperature Range	-30° to +110° F
Relative humidity	8 to 100%
Maximum rainfall in 24 hours	6.7 inches
Maximum snowfall in 24 hours	18.4 inches
Maximum wind speed	71 mph
Freezing rain	average of 1 time per year
Elevation	4,330 feet

All facilities shall be designed to accommodate safe storage and/or removal of snow, melting snow, and ice.

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Chapter 20	Elevators/Escalators	(Not Used)
Chapter 21	Operations and Maintenance	(Not Used)
Chapter 22	Safety and Security	(Not Used)
Chapter 23	System Assurance	(Not Used)
Chapter 24	Parking Deck	(Not Used)
Chapter 25	Railroad (Freight)	(Not Used)

END OF CHAPTER 1.



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Chapter 2 Environmental

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CHAPTER 2 ENVIRONMENTAL CRITERIA

2.1 General

This section provides guidance and criteria for implementing environmental features into the Utah Transit Authority's (UTA) light rail projects. It also establishes criteria by which to avoid, minimize, and/or mitigate environmental impacts.

Prior to final design and construction of a light rail project, the project will undergo an environmental review in compliance with the National Environmental Policy Act (NEPA) if federal funding is being sought, or in compliance with UTA's internal Environmental Review Process for non-federally funded projects. This review shall include an approved Final Environmental Impact Statement (FEIS) and a Record of Decision (ROD) or a Final Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) issued by the Federal Transit Administration for federally-funded projects, or a Final Environmental Study Report (FESR) and Decision Document (DD) for locally-funded projects. The environmental document for each project will contain mitigation measures, which are intended to reduce the level of adverse effects resulting from implementation of the project. These measures will be formally adopted as part of the project, incorporated into the project design, and reflected in the construction contract documents.

During project construction and operation, all activities will be monitored for compliance with the mitigation measures as developed in the environmental document. UTA will prepare a Mitigation Monitoring Plan for each project to ensure all applicable permits are in place and all mitigation commitments are implemented appropriately. The UTA Environmental Studies Manager will oversee compliance monitoring for the project.

2.2 Natural Environment Criteria

2.2.1 *Geologic Hazard*

UTA's service area is seismically active. The maximum magnitude earthquake is 7.25 with a recurrence interval on the order of 1,900 to 2,000 years according to the initial geotechnical investigations. The structures are assigned a Seismic Performance Category C in accordance with the American Association of State Highway and Transportation Officials (AASHTO) requirements. This is based on a system of categories A through D with D being the most severe. A geotechnical report shall be prepared for each rail transit project.

2.2.2 *Air Quality*

Project facilities which provide for the movement of automobiles (i.e., roads and parking lots) shall be designed so as to minimize delays and vehicle idling, thereby minimizing increased contributions to local carbon monoxide levels. A "hot spot analysis" will be conducted as necessary as part of the environmental documentation to determine if transit-related traffic accessing the stations will affect the level of service at nearby intersections. A dust control plan must be submitted to the Utah Division of Air Quality for any construction activities that will disturb more than ¼ acre.

2.2.3 *Transit Noise and Vibration*

This section presents the noise and vibration design criteria applicable to the operation of vehicles/train sets, noise from transit support facilities, and noise attributable to construction of the system, and describes the methods to be employed to mitigate noise impacts. The primary goal is to minimize the

adverse noise and vibration impacts on the community and, where necessary and appropriate, to provide feasible and reasonable noise and vibration mitigation measures.

2.2.3.1 Project Noise

When conducting an environmental study for a proposed Capital Development project, UTA will assess the potential for noise and vibration impacts from the proposed project in accordance with FTA's guidance document *Transit Noise and Vibration Impact Assessment* (May 2006). The findings will be documented in a noise study report and/or the project's environmental document.

The noise study will identify noise sensitive receivers that will have moderate or severe noise impacts from the proposed action, and noise mitigation measures will be developed for those receivers where reasonable and feasible. Mitigation commitments will be specified in the environmental document and may include measures such as special track work at crossovers in noise sensitive areas, rail lubrication on sharp curves, construction of sound barriers (such as walls or berms) between the receiver and the noise source, and building noise insulation. These mitigation commitments will be incorporated into the project design and construction.

UTA has also developed vehicle noise specifications for both its light rail and commuter rail vehicles. These specifications will be followed to minimize noise impacts from new vehicles.

2.2.3.2 Horn Noise

Quiet zones may be employed to eliminate horn use and noise except in emergencies. Quiet zones will be established in coordination with the Utah Department of Transportation, affected cities, and the Federal Railroad Administration. Affected cities have the responsibility to apply for quiet zones. Upon request, UTA will provide assistance to cities in the application process.

2.2.3.3 Yard and Shop Noise

The noise levels from yard and shop activities generally will satisfy the daytime noise criteria at most of the residential sites near the yard site. UTA will ensure that noise-producing yard activities will be limited to daytime hours to the extent possible. Nighttime yard activities, other than trains moving in the yard, will be performed inside a closed building, which is the normal practice in maintenance yards.

2.2.3.4 Construction Noise and Vibration

Construction noise is regulated by local ordinances and by U.S. Environmental Protection Agency emission standards for construction equipment. Construction contractors will be contractually required to meet all federal, state, and local noise requirements and ordinances. Noise mitigation measures will be implemented in accordance with the mitigation requirements contained in the environmental document.

2.2.4 Water

2.2.4.1 Surface Water Quality

The addition of new fixed facilities will increase the potential for water runoff. This potential extends to both the construction and operation phases of a project. A Utah Pollutant Discharge Elimination System (UPDES) storm water permit shall be obtained by the contractor from the Utah Division of Water Quality prior to the start of construction. As part of this permit, the contractor will develop a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP will include sedimentation and erosion control best management practices (BMPs) for the elimination or reduction of sediment during construction. Methods that may be employed during construction include silt fences, temporary seeding, temporary diversions, sediment traps, and temporary stream crossings. The SWPPP will also include measures for spill

prevention, containment, and an emergency cleanup plan. Any required permits from the local storm water management authority shall also be obtained prior to the start of construction.

Catch basins, curbing, culverts, gutters, and storm sewers shall be constructed, as necessary, for the permanent control of water runoff during the operation phase of the project. No storm water runoff resulting from the project shall be permitted to enter canals, in compliance with applicable local requirements. Any proposed yard and maintenance facilities shall be designed with storm drain systems, filters, traps, grit chambers, and so forth, in accordance with municipal water design standards and in compliance with UPDES storm water regulations.

2.2.4.2 Streams

Any required stream alteration permits shall be obtained from the Utah State Engineer's office. The permit applications will be reviewed as required by the U.S. Army Corps of Engineers.

2.2.4.3 Floodplains

Construction of the project has the potential to impact regulatory floodways and floodplains within the corridor. Local county flood control and Federal Emergency Management Agency (FEMA) guidelines shall be observed for the design of the permanent structures and construction activities. Disturbances to creek channels should be held to a minimum.

Construction in designated floodplains will require a Section 404 permit from the U.S. Army Corps of Engineers. Construction impacts shall be addressed to mitigate potential water quality and flooding problems.

2.2.4.4 Wetlands

Wetlands within or adjacent to project right-of-way will be delineated in the project's environmental studies. The type and extent of the disturbance shall be coordinated with the U.S. Army Corps of Engineers. Replacement wetlands shall be provided as part of the rail transit project if required by the permit requirements and in accordance with applicable laws and regulations.

Construction activity shall have a short-term disruption affect and portions of these wetlands could be displaced. The proposed mitigation is to minimize disturbance to these areas, and where direct impacts occur, to restore the wetlands to as near original condition as possible, or as prescribed by the Army Corps of Engineers.

2.2.5 Vegetation/Wildlife

As a result of construction, it may be necessary to remove some existing vegetation or disturb existing wild life. In order to mitigate these losses, the following criteria shall apply:

- UTA will comply with all local landscaping ordinances
- Disturbed areas will be revegetated as quickly as possible
- Where existing vegetation is removed, new landscaping shall be planted where possible and appropriate. The placement and types of which vegetation shall be specified in an established landscaping plan.
- The landscaping plan should include a master plant list which identifies new vegetation that is designed to conform to the surrounding environment and be consistent with the operations and maintenance requirements of the rail transit system.

- The landscaping plan may extend to the system stations, parking, and public areas of fixed system facilities.
- A program shall be developed as part of the overall maintenance-of-way procedures for the rail system which shall provide for the regular maintenance of system-related landscaping.
- If required, the project design and construction shall be coordinated with the U.S. Fish and Wildlife Service.

2.2.6 Hazardous Waste Sites

As defined in federal and state statutes, hazardous substances, hazardous wastes, and special wastes are regulated in all aspects, from their generation, storage, transport, and disposal, including associated reporting and record keeping. In the development and implementation of rail projects, UTA shall consider hazardous substances, hazardous wastes, and special wastes and shall comply with all applicable regulations and controls.

Due care shall be exercised to determine whether hazardous substances, hazardous wastes, or special wastes may be present on, adjacent, or in close proximity to property being considered for use in UTA projects. A property may be impacted by such substances or wastes that are located within the property boundaries as well as migration to the property from off-site sources. The presence of hazardous substances, hazardous wastes, or special wastes may impact all aspects of a rail transit project, including property acquisition and project construction.

For properties being considered for acquisition, a “due diligence” Phase I Environmental Site Assessments (ESA) or Property Transaction Screens (PTS) shall be conducted to determine the presence of such substances or wastes in accordance with the current edition of the American Society for Testing and Material (ASTM) Standard E-1527, “Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process.” The Phase I ESA or PTS shall be conducted prior to acquisition. Acquisition of an interest in a property determined to contain such substances shall be avoided unless the risks and liabilities of such acquisition can be justified. If avoidance is not feasible, proper management of substances and wastes shall conform to all applicable laws and regulations.

For properties where acquisition is not a factor, a Phase I ESA or PTS shall be conducted to identify potential construction-related impacts associated with such substances and wastes. The Phase I ESA shall use the ASTM Phase I ESA standards as a guideline to determine the appropriate level of environmental inquiry necessary to identify and evaluate project specific construction impacts. Once construction impacts have been identified, proper management of substances and wastes encountered during construction shall conform to all applicable laws and regulations.

2.2.7 Energy Conservation

In order to reduce energy consumption, conservation features and operating procedures shall be developed for operating systems and subsystems as part of final design activities.

2.3 Socioeconomic Environment Criteria

2.3.1 Displacement/Relocations

For each rail transit project, UTA’s relocation program will provide for studies of the availability of equivalent accommodations, definitions of eligibility for assistance, procedures for dealing with relocations, payment methods, procedures for processing claims and typical schedule event times to effect

relocations. This program will provide relocation moving payments to cover actual moving expenses and replacement housing payments or rent supplements where an owner or tenant will have to purchase or rent property at a higher cost or lose a favorable financing arrangement. All relocations shall be carried out in accordance with applicable state laws and requirements. For federally-funded projects, all relocations shall be carried out in accordance with the Federal Uniform Relocation Assistance and Real Property Acquisitions Act of 1970 (Public Law 91-646), as amended.

2.3.2 Safety/Security

The implementation of a rail transit system carries with it the potential for crimes against persons and property, extending to vehicles, stations, parking areas, and other public areas created by the system. In order to minimize this potential, all system public areas shall be designed to promote maximum safety and security for all system patrons. Specific design measures which shall be employed are discussed in the design criteria for the specific system element.

2.3.3 Historic, Architectural, Archaeological, and Cultural Resources

Section 106 of the National Historic Preservation Act (NHPA) requires that federal agencies, or state agencies that receive federal assistance, consider any effects a project may have on significant cultural resources. In addition, Section 9-8-404 of the Utah Code Annotated (UCA) requires that state agencies “take into account” how their activities will affect historic properties. As part of the environmental study for the rail transit project, UTA will identify all historic resources located within the project’s area of potential effect (APE) that are on or eligible for the National Register of Historic Places (NRHP) and will consult with the State Historic Preservation Office (SHPO) to determine the effect of the project on those resources. For projects that will have an Adverse Effect on eligible historic resources, UTA will develop a Memorandum of Agreement (MOA) with the SHPO that identifies the mitigation measures that will be incorporated into the project. For federally-funded projects, FTA will also be a party to the MOA.

UCA 63-73-19 protects significant paleontological resources included in or eligible for inclusion in the State Paleontological Register. This regulation requires that state agencies take into account the effect of the project on paleontological resources and allow the director of the Utah Geological Survey (UGS) an opportunity to comment. If the project would have No Effect on paleontological resources, no further action is necessary. If there may be an effect on paleontological resources, documentation and surveys may be required.

2.3.3.1 Summary of MOA Stipulations

For sites or properties that are found to be eligible for inclusion in the NRHP, and which will be adversely affected by the rail project, UTA will consult with the SHPO to develop an appropriate mitigation plan. This mitigation plan will be documented in the MOA. Types of mitigation include but are not necessarily limited to:

- Mitigation for Adverse Effects on historic structures may consist of intensive-level survey documentation. A qualified architectural historian who meets the Secretary of the Interior’s standards for historian or architectural historian must conduct the fieldwork, research, and formal documentation of each building in accordance with the SHPO’s *Intensive Level Survey—Basic Survey Standards* (Utah State Historic Preservation Office 2007b).
- Mitigation may consist of thorough Historic American Engineering Record documentation. A qualified historian or archaeologist who meets the Secretary of the Interior’s standards for historian or historical archaeologist must conduct the fieldwork, research, and formal documentation of the resource in accordance with the Secretary of the Interior’s *Standards and*

Guidelines for Architectural and Engineering Documentation, consisting of historical research, measured drawings, and large-format black-and-white photography.

- **Data Recovery Plans:** In consultation with the SHPO, UTA will develop data recovery *plans* for *archaeological* sites where it is determined that this treatment will be the most appropriate and effective, considering the design requirements of the rail project. Plans will be consistent with the Secretary of the Interior's Standards and Guidelines for Archaeological Documentation.
- **Preservation in Place:** In consultation with the SHPO, UTA will develop plans for preservation in place for archaeological sites where it has been determined that this treatment will be the most appropriate and effective, considering the design requirements of the rail project. UTA will implement approved preservation plans to ensure that the archaeological properties selected for such treatment are preserved during construction.
- **Educational Component:** The project may include an educational component as mitigation for impacts to archaeological sites. The format of the educational component would be developed by UTA in consultation with the SHPO. The educational materials produced could be in the form of a popular report suitable for distribution to the public and presenting the results of the archaeological investigations or, as display boards mounted in the trains.

2.3.3.2 Inadvertent Discovery

If buried cultural or unanticipated archaeological resources are inadvertently discovered during ground-disturbing activities, the contractor will contact a qualified archaeologist who, in consultation with UTA and the SHPO, will determine the appropriate action to pursue regarding the resource. Work will not resume in the area until approval is given by the UTA Project Manager, in consultation with the SHPO.

Buried human remains that were not identified during research or field surveys could be inadvertently unearthed during excavation activities, which could result in damage to the human remains. If human remains of Native American origin are discovered during ground-disturbing activities, it is necessary to comply with state laws relating to the disposition of Native American burials, following state regulation UCA 9-9-401 and the Utah Native American Graves Protection and Repatriation Act of 1992.

Utah State Code (63-73-11 through 63-73-19) currently states that paleontological resources are important and requires the preservation of critical fossil resources on State lands. If paleontological resources are unearthed before or during construction, a qualified paleontologist should be notified. The paleontologist then will salvage the fossils and assess the necessity for further mitigation measures, if applicable.

2.3.4 Visual

The UTA rail project may affect visual quality at station locations and track work areas. These impacts may result from removal of existing vegetation and from construction of station or parking lot infrastructure adjacent to residential areas or historic resources. Areas disturbed by construction activities will be re-vegetated as discussed in Section 2.2.5. Design standards for the visual characteristics of stations will be developed in consultation with local jurisdictions through the design review process.

2.3.4.1 Lighting

Lighting design shall incorporate CPTED (crime prevention through environmental design) design standards. Area and guideway lighting fixtures and standards shall incorporate directional shielding where needed to avoid the intrusion of unwanted light and glare into adjacent sensitive land uses, such as residential areas. Lighting should be planned with consideration to growth of landscaping. Lighting plans may be subject to local jurisdictional requirements and approval.

2.3.4.2 Visual Clutter

With regard to the specific visual treatment of traction power substations and the overhead catenary system, the following criteria apply:

- Screen from sensitive adjacent land uses, such as residential areas, as directed in the environmental process.
- Lighting and security equipment shall be shielded from the view of adjacent sensitive land uses.
- Local ordinances for visual screening shall be followed.

2.3.4.3 Urban Design

The goal of the rail transit system is to provide economical, functional stations that blend with the land uses and community patterns around them. At downtown station sites, historic station sites, mixed-use station sites, and along the corridor, urban design issues shall be addressed in ways that achieve that goal. Urban design plans may be subject to local jurisdictional zoning or design regulations.

2.3.5 Public Parks and Greenways

Section 4(f) of the Department of Transportation Act of 1996, as amended (49 USC § 303) protects historic, cultural, public parks, and wildlife refuges from conversion to transportation use unless it can be demonstrated that there is no prudent or feasible alternative. For all federally-funded projects, a 4(f) evaluation will be conducted if there is a federal EIS or EA process, documenting the reasons for the use of land, the benefits associated with that use, and lack of prudent or feasible alternatives for avoiding the resource.

2.3.6 Environmental Justice

UTA will consider potential impacts to minority, low-income and disadvantaged populations in the planning and design of its rail and bus service systems. In compliance with NEPA regulations, environmental documents will identify any potential for disproportionate impacts to these populations. UTA will conduct public outreach to inform and consult with environmental justice populations.

2.4 Traffic and Transportation Criteria

In areas around rail transit stations, increases in local traffic congestion may result. Bus service shall be restructured to provide feeder service to rail transit stations. Additional or revised traffic signals and transportation system management (TSM) improvements shall be implemented, as determined necessary, in consultation with local jurisdictions.

2.5 Construction Criteria

The project construction specifications shall be written to require compliance with all appropriate environmental regulation guidelines and permit requirements. When required, construction impact mitigation plans shall be included in the construction packages. Construction noise and vibration limits shall be defined by the regulations of each jurisdiction.

2.5.1 Impacts to Businesses

The following mitigation shall be considered to minimize the impact of construction activities on businesses adjacent to the project:

- Minimize the length of time that any street block is closed.
- Schedule construction during off-peak traffic periods in sensitive areas, if possible.
- Maintain maximum possible number of traffic lanes for operation during construction periods.
- Maintain sidewalks for operation or provide alternative walkways.
- Maintain the visibility of businesses through coordination with local merchants, using temporary signing and other appropriate special measures.

2.5.2 Impacts to Emergency Vehicle Operation

Mitigation measures to facilitate the operation of emergency vehicles during the construction phase may include:

- Implementing traffic control measures to reduce congestion (i.e., use of barriers, proper identification of detours, and proper legible signing)
- Informing emergency services providers of construction schedules and activities
- Developing alternative emergency access routes to affected facilities such as hospitals

END OF CHAPTER 2.



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Chapter 3 Track Alignment & Vehicle Clearance

Revision 4, November 2007

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0				1997
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CHAPTER 3 TRACK ALIGNMENT AND VEHICLE CLEARANCE

3.1 General

The criteria for the alignment of light rail transit, as set forth in this chapter, have been established to provide:

- Optimum safety
- Passenger comfort
- Ease of maintenance

Light rail transit has three classifications of track:

- Exclusive LRV track in dedicated right-of-way
- Joint use LRV/freight track in dedicated right-of-way
- Exclusive street median running with traffic signal protection

Each segment of track will be designed according to the design criteria for its classification as outlined in this Chapter.

The criteria in this Chapter are supplemented by the track work design criteria in Chapter 4.

3.2 Nomenclature and Definitions

3.2.1 *Horizontal Alignment*

- D_A = degree of curvature, arc definition
 D_c = degree of curvature, chord definition
 I = tangent intersection angle (degrees)
 E_a = actual superelevation (inches)
 E_u = unbalanced superelevation (inches)
 E_q = $E_a + E_u$ = equilibrium superelevation (inches)
 L_c = length of circular curve (feet)
 L_s = length of spiral (feet)
 R = radius of curve (feet)
 T = tangent length (feet)
 V = design speed (mph)

3.2.2 *Vertical Alignment*

- R_v = minimum radius of curvature of the vertical curve (feet)
 L_{vc} = length of vertical curve (feet)
 G_1 = percent grade of approaching tangent

- G_2 = percent grade of departing tangent
- T = length of uniform grade tangent (feet)
- $G_1 - G_2$ = algebraic difference in gradients connected by the vertical curve (percent)
- V = design speed (mph)

3.3 Exclusive LRV Track in Dedicated Right-of-Way Alignment Criteria

3.3.1 Horizontal Alignment

The horizontal alignment for the LRV track in dedicated right-of-way shall consist of tangents, circular curves, and transition spirals, and shall be designed for a maximum design speed, determined by station spacing, where right-of-way and operational constraints permit. The track alignment shall be based on a maximum civil speed for each curve, with the actual superelevation to be established based on the maximum operational running speed that is less than or equal to the civil speed. This is to insure that the curve's actual superelevation (E_a) is not greater than the equilibrium superelevation (E_q) that results during regular everyday operation at more moderate speeds.

3.3.1.1 Tangents

The following minimum tangent lengths between circular curves or spiral transitions shall be observed:

- T (desirable min.) = $3 * V$
- T (absolute min.) = 30'

The 30' minimum shall be used only with approval from the UTA Light Rail Transit Project Director.

At station platforms use the following minimum tangent lengths (platform length is defined by a four-car train):

$$\text{(desirable)*} = (\text{length of platform}) + (45' \text{ at each end}) = (\text{length of platform}) + (90')$$

* If the desirable distance is not attainable, the clearances between the platform and the LRV middle ordinate and end overhang shall be checked to provide the minimum required clearance between the LRV and the platform structure as defined in the vehicle clearance section.

For curves in the same direction with a connecting tangent less than 60 feet, the adjoining curves shall be connected by a spiral transition to replace the resulting broken back curve configuration.

All turnouts shall be located on tangent track. Points of switches shall be located a minimum of 45 feet from the ends of station platforms. Points of switches and frog heels shall desirably be located a minimum distance of 60 feet from points of horizontal curvature of mainline track. In situations where this is not practical, lesser distances are permitted with the approval of the UTA Light Rail Transit Project Director.

3.3.1.2 Circular Curves

Circular curves shall be defined by the centerline of track radius measured in feet.

Degree of curvature, where required for calculation purposes, shall be defined by the arc definition of curvature as determined by the following formula:

$$D_A = 5729.58' / R$$

The desired minimum radius for mainline track shall be the minimum radius that is required to achieve the maximum civil speed for the allowable equilibrium superelevation and corridor constraints. The corresponding equilibrium superelevation for a given curve shall result in lateral acceleration less than or equal to 0.10g.

The absolute minimum radius is defined as 82 feet, which corresponds to the turning capabilities of the composite LRV.

The length of the circular curve, not including connecting spirals, shall be as follows:

$$\text{Desirable minimum } L_C = 3 * V, \text{ where } V = \text{design speed, mph}$$

$$\text{Absolute minimum } L_C = 60 \text{ feet}$$

3.3.1.3 Spiral Transitions

The minimum length of spiral can be defined by the formula:

$$L_S (\text{min.}) = 31 * E_a$$

For a spiral segment in-between two circular curve segments:

$$L_S (\text{min.}) = 31 * (E_{a_2} - E_{a_1})$$

Spiral transitions shall be used at all mainline curves of radii of less than 10,000 feet (where possible) to provide a smooth transition between the tangent track and circular curve track. This transition is required to eliminate the abrupt change in direction of the vehicle wheel path from tangent track to curved track, to provide a smooth transition for the rate of change of applied superelevation, and to provide a comfortable transition for the rate of change of lateral acceleration.

Transition spirals shall be true clothoid spirals where the instantaneous radius varies directly with the distance from the point of tangency. Examples include the Barnett Spiral, the Hickerson Spiral, and other similar mathematically defined curves as published in standard route geometry reference books and used in commercial coordinate geometry computer programs.

The minimum length of transition spiral shall be the largest length as determined by the following formulas:

- (1) $L_S = 31 * E_a$ (track twist)
- (2) $L_S = 1.17 * E_a * V$ (vehicle roll limited to 1.2 degrees per second)
- (3) $L_S = 1.22 * E_u * V$ (jerk rate less than or equal to 0.04 g/sec)
- (4) $L_S = 60$ feet (absolute minimum)

where,

L_S = minimum length of transition spiral, feet

E_a = actual superelevation, inches

V = design speed, mph

E_u = unbalanced superelevation, inches

Twist = rate of change of cross level of track due to applied superelevation

Jerk rate = rate of change of lateral acceleration

If a jerk rate less than 0.04 g/sec cannot be maintained to achieve a desirable design speed, the designer may, with written UTA approval, increase the jerk rate up to a maximum of 0.16 g/sec.

Where compound curves are used, the minimum length of connecting transition spiral shall be the largest length as determined by the following formulas:

- (1) $L_S = 1.17*(E_{a1} - E_{a2})*V$
- (2) $L_S = 1.22*(E_{u1} - E_{u2})*V$
- (3) $L_S = 31*(E_{a2} - E_{a1})$
- (4) $L_S = 60$ feet (absolute minimum)

where,

- L_S = minimum length of compounding spiral, feet
- a_1 = actual superelevation of first curve, inches
- E_{a2} = actual superelevation of second curve, inches
- E_{u1} = unbalanced superelevation of first curve, inches
- E_{u2} = unbalanced superelevation of second curve, inches
- V = design speed, mph

Spiral transitions are not required in special track work.

3.3.1.4 Superelevation

The design speed of a given curve shall be limited to the maximum allowable speed as determined by the following formula based on a standard track gauge of 4 feet 8½ inches:

$$Eq = E_a + E_u = \frac{3.96 V^2}{R}$$

where,

- Eq = equilibrium superelevation
- E_a = actual superelevation, inches
- E_u = unbalanced superelevation, inches
- V = design speed, mph
- R = curve radius, feet

The equilibrium superelevation is the sum of the actual superelevation (E_a) and the unbalanced superelevation (E_u). When superelevation is applied it shall be in accordance with the following requirements:

- E_a shall have a minimum value of 1 inch and a maximum value of 6 inches. When the calculated required E_a is less than ½ inch, 0 shall be used. When it is ½ inch or greater, but not more than 1 inch, 1 inch shall be used.
- E_a shall be specified in ¼-inch increments. When the calculated requirement is not a whole-number multiple of ¼-inch, the next higher whole-number multiple of ¼-inch shall be used.

- The unbalanced superelevation (Eu) shall not be greater than plus 4 inches. When zero Ea is used, the value of Eu shall not exceed 2 inches.
- If maximum Eu of 4 inches cannot be maintained to achieve a desirable design speed, the designer may, with written UTA approval, increase the Eu up to maximum of 6½ inches.
- On constant speed curves, the value of Eu shall vary uniformly from 0 when $Ea + Eu = 1.00$ to 2.50 inches when $Ea + Eu = 8.50$ ".

These additional controls result in the following formula:

$$Eu = 1 - \frac{Ea}{2}$$

and

$$Ea = \frac{2.64 V^2}{R} - 0.66$$

When the following maximum values of Ea or Eu are exceeded, a limit shall be placed on the design speed of a curve:

$$Ea \text{ (direct fixation track)} = 6 \text{ inches}$$

$$Ea \text{ (ballasted track)} = 4 \text{ inches}$$

$$Eu \text{ (lateral acceleration } < 0.10g) = 4 \text{ inches}$$

At special track work, the actual superelevation (Ea) shall be 0 until the unbalanced superelevation reaches 3 inches. At this point, a limit shall be placed on the design speed through the turnout.

The top of inside rail in a curve shall be set to the design profile grade and the required superelevation shall be applied to the outside rail.

3.3.2 Vertical Alignment

3.3.2.1 Tangents

The minimum length of constant tangent grade shall be:

$$T \text{ (desirable minimum)} = 3 V$$

$$T \text{ (absolute minimum)} = 60 \text{ feet}$$

At stations, the tangent grade shall extend a desirable minimum distance of 100 feet beyond each end of platform. The absolute minimum distance is 0 feet from a point at the end of platform.

All special track work shall be located on tangent grade and the associated points of switches/frog heels shall be located a desirable minimum distance of 60 feet from the point of vertical curvature or grade change. The absolute minimum distance depends on the clearances required for the specific turnout geometry and rail joint locations.

3.3.2.2 Grades

- Mainline Grade:

$$\text{Desired maximum grade (1,500 feet or greater)} = 4\%$$

$$\text{Maximum short sustained grade (less than 1,500 feet)} = 6\%$$

- Absolute maximum grade – ballasted track 6%
- Desirable maximum grade – embedded and direct fixation track 6%
- Absolute maximum grade – embedded and direct fixation track (subject to UTA approval) 8%

- Station Area Grade:

- Desirable max. grade = 0.5%
- Absolute max. grade = 2.0%*

* ADA requirements must be checked.

3.3.2.3 Vertical Curves

All vertical curves shall be defined by a parabolic curve having a constant rate of grade change as expressed by the formula:

$$\text{M.O.} = \frac{(G_1 - G_2) * L}{800}$$

where,

M.O. = middle ordinate distance from PVI to curve, feet

$G_1 - G_2$ = algebraic difference in grades, expressed in %

L = length of vertical curve, feet

Vertical curves shall be provided at all tangent grade intersections where:

$$(G_1 - G_2) > 0.50\%$$

where,

$G_1 - G_2$ = algebraic difference in grades, expressed in %

3.3.2.4 Vertical Curve Lengths

The required length of vertical curve shall be the largest length as calculated from the following formula, rounded off to the nearest 1 foot:

$$L \text{ (desirable)} = 200 (G_1 - G_2)$$

$$L \text{ (preferred minimum)} = 100 (G_1 - G_2)$$

$$L \text{ (absolute min. crest curve)} = \frac{(G_1 - G_2)V^2}{25}$$

$$L \text{ (absolute min. sag curve)} = \frac{(G_1 - G_2)V^2}{45}$$

where,

L = minimum length of vertical curve, feet

$G_1 - G_2$ = algebraic difference in grades, expressed in %

V = design speed, mph

Vertical curve lengths less than absolute minimum requires approval from UTA LRT Project Director.

3.4 Joint Use LRV/Freight Track Alignment Criteria

3.4.1 Horizontal Alignment

The horizontal track alignment for combined LRV and freight train use in a dedicated rail corridor shall be designed in conformance with the applicable requirements of AREMA's *Manual for Railway Engineering*, latest edition, and any specific requirements of the railroad company. Unless specified otherwise in this section of the criteria, parameters established for exclusive LRV track in Section 3.3 shall apply.

3.4.1.1 Tangents

The following minimum tangent lengths between circular curves and/or spiral transitions shall be observed:

$$T \text{ (desirable min.)} = 300'$$

$$T \text{ (absolute min.)} = 100'$$

3.4.1.2 Circular Curves

The desired minimum radius for joint use track shall be the minimum radius that is required to achieve the maximum design speeds for both the freight train and the LRV based on the maximum allowable equilibrium superelevation requirements as defined in Section 3.4.1.4, Superelevation.

For archaic reasons, railroad companies in the U.S. traditionally use the chord definition for curves and typically object strenuously when they are presented with plans for the realignment of their tracks which use the arc definition. Therefore, where tracks are designed for use by a freight railroad company, whenever possible and practical, the radii selected for curves shall be such that they result in an even degree, half degree, or quarter degree of curve when the curve is expressed in the chord definition. The relationship between degree of curve (Dc) and radius (R) in the chord definition is established by the following formula:

$$R = \frac{50}{\sin \frac{1}{2} Dc}$$

Other chord definition parameters and conventions, such as the determination of curve lengths using chords, shall not be used. The identification of the equivalent chord definition degree of curvature for a curve that will otherwise be calculated using arc definition parameters is strictly a convenience for the use of the railroad in review of the plans and for the maintenance of tracks which they will own.

The length of the circular curve, not including connecting spirals, shall be as follows:

$$\text{Desirable minimum} \quad L_c = 3 V \text{ where } V = \text{design speed, mph}$$

$$\text{Absolute minimum} \quad L_c = 100 \text{ feet}$$

3.4.1.3 Spiral Transitions

The minimum length of transition spiral shall be the largest length as determined from the following formulae:

$$L_S = 62 E a \text{ (track twist at } \frac{1}{2}'' \text{ per foot)}$$

$$L_S = 1.17 E V \text{ (vehicle roll angle limited to 1.2 degrees per second)}$$

$$L_S = 1.22 E u V \text{ (jerk rate less than or equal to .04g/sec)}$$

$$L_S = 60 \text{ feet (absolute minimum)}$$

where,

L_S = minimum length of transition spiral, feet

E = actual superelevation, inches

V = design speed, mph

E_u = unbalanced superelevation, inches

3.4.1.4 Superelevation

The design speed of a given curve shall be limited to the maximum allowable speed as determined by the following formula based on a standard track gauge of 4' - 8 1/2 ".

$$E_a + E_u = \frac{4.01 V^2}{R}$$

where,

E_a = actual superelevation, inches

E_u = unbalanced superelevation, inches

V = design speed, mph

R = curve radius, feet

Superelevation shall be based on a maximum allowable speed of 40 mph for freight traffic and 65 mph for LRV. The actual superelevation shall be established for the maximum LRV design speed such that the resulting equilibrium superelevation for the freight vehicle is not negative.

The equilibrium superelevation is the sum of the actual superelevation (E) and the unbalanced superelevation (E_u). When the following maximum values of these are exceeded, a limit shall be placed on the design speed of a curve:

$$E_{a_{max}} = 4.0 \text{ inches}$$

$$E_{u_{max}} = 3.0 \text{ inches for light rail vehicle}$$

$$E_{u_{max}} = 1.5 \text{ inches for freight rail vehicles}$$

3.4.2 Vertical Alignment

3.4.2.1 Tangents

Minimum length of uniform grade tangents:

$$T \text{ (desirable min.)} = 300'$$

$$T \text{ (absolute min.)} = 100'$$

3.4.2.2 Grades

- Mainline Grade:

$$G \text{ (max.)} = 1.0 \%$$

If existing freight rail grade is greater than 1%, an exception may be made.

- Station Area Grade:

desirable max. = 0.5%

absolute max. = 2.0%*

* *ADA requirements must be checked.*

3.4.2.3 Vertical Curve Lengths

The lengths of vertical curves shall be calculated as follows, rounded up to the nearest 10':

$$\text{crest curves: } L = 250 (G_1 - G_2)$$

$$\text{sags: } L = 500 (G_1 - G_2)$$

3.5 LRV Track in Existing Streets Alignment Criteria

3.5.1 Horizontal Alignment

Street-running track alignment design shall permit the LRVs to run at the legal street speed limit and per MUTCD at Highway–LRT at-grade intersections. The applicable geometric design criteria for the streets shall be used for the design of the tracks. Speed restrictions for safe operations at curves, turnouts and crossovers in a street environment will be established and coordinated with the city. Unless otherwise noted in this section, the design requirements outlined in Section 3.3 are the desirable values for the street-running track where existing street conditions allow.

3.5.1.1 Tangents

On city streets, due to right-of-way or other alignment constraints, a tangent may not be required between spirals in reverse curvature where the speed is limited to 20 miles per hour and superelevation is not provided.

3.5.1.2 Circular Curves

- Minimum curve radius for street running tracks:

$$R (\text{desirable minimum}) = 535 \text{ feet (20 mph at } E=0 \text{ and } E_u=3'')$$

$$R (\text{absolute minimum}) = 82 \text{ feet}$$

- Minimum length of circular curve:

$$L (\text{desired minimum}) = 3 V$$

$$L (\text{absolute minimum}) = 60 \text{ feet}$$

where,

$$L = \text{length of circular curve, feet}$$

$$V = \text{speed, mph}$$

3.5.1.3 Spiral Transitions

Spiral transitions shall be used for all street running curves where the calculated equilibrium superelevation is greater than or equal to 1 inch.

The length of spiral transitions shall be as defined in Section 3.3.1.4, unless otherwise prohibited by street section or operations constraints. In such cases, the speed limit of the curve shall be restricted to meet the established criteria based on the available spiral transition lengths.

3.5.1.4 Superelevation/Cross Slope

For street-running track, superelevation/cross slope must be designed to accommodate the existing street sections and cross traffic and to assure positive drainage toward storm water inlets. When street sections are not an issue, the criteria in Section 3.3.1.4 shall govern.

3.5.2 Vertical Alignment

3.5.2.1 Tangents

The street-running rail must meet the profile of the existing street and no minimum tangent length between curves shall be required.

3.5.2.2 Grades

- Embedded Track Grade:
min. = 0.5%
- Station Area Grade:
desirable max. = 0.5%
absolute max. = 2.5%*
** ADA requirements must be checked.*
- Existing conditions may require exceeding the maximum 2.5% grade for on-street stations. The designer shall notify the UTA Light Rail Project Director before proceeding with the design of a station with a grade greater than 2.5%.

3.5.2.3 Vertical Curve Lengths

The minimum requirements shown in Section 3.3.2.4 are the preferred standards; however, existing conditions may require exemptions on a case-by-case basis.

3.6 Lead and Yard Track and Freight Industrial Track Alignment Criteria

3.6.1 Horizontal Alignment

The criteria in this section are intended to set the minimum standards for track configurations for secondary track. The horizontal alignment in these track areas is often constrained by limited space and exemptions from the criteria may be required. Any exceptions shall be subject to the review and acceptance of UTA.

The design speed for lead and industrial tracks shall be 10 miles per hour. Yard track shall be designed for 20 miles per hour. Superelevation is not required but shall be used when conditions permit. All design criteria shall be the same as for the exclusive LRV track or for joint use LRT and freight track as applicable except as noted in this section.

3.6.1.1 Tangents

The minimum tangent length is:

$$T (\text{min.}) = 50'$$

3.6.1.2 Circular Curves

Circular curves shall be provided for sidings and yard tracks when:

The minimum radii for the LRT yard is

$$R \text{ (min.)} = 100'$$

$$R \text{ (absolute min.)} = 82'$$

For lead tracks

$$R \text{ (min.)} = 300'$$

$$R \text{ (absolute min.)} = 82'$$

and for freight industrial spurs:

$$Dc \text{ (desirable max.)} = 12^{\circ}30' \text{ (chord definition)}$$

$$R \text{ (min)} = 459.28'$$

Freight industrial spurs may be sharper than the value above if the existing railroad freight spur includes curvature sharper than that.

3.6.1.3 Spiral Transitions

Although not required, spiral curves are preferred for design speeds greater than 10 miles per hour. Spirals shall be used on any track where superelevation is applied.

3.6.1.4 Superelevation

The yard, shop, and industrial tracks shall not be superelevated. Lead tracks shall be superelevated when conditions permit.

3.6.2 Vertical Alignment

Yard and storage tracks shall be either level or create a sag condition whenever possible so that parked rolling stock cannot drift out onto main tracks.

3.6.2.1 Grades

- Yard Tracks
 - desirable max. = 0%
 - absolute max. = 1%
- Lead and Industrial Tracks
 - desirable max. = 0.2%
 - absolute max. = 1.0%

Grade compensations are not required.

3.7 Clearances

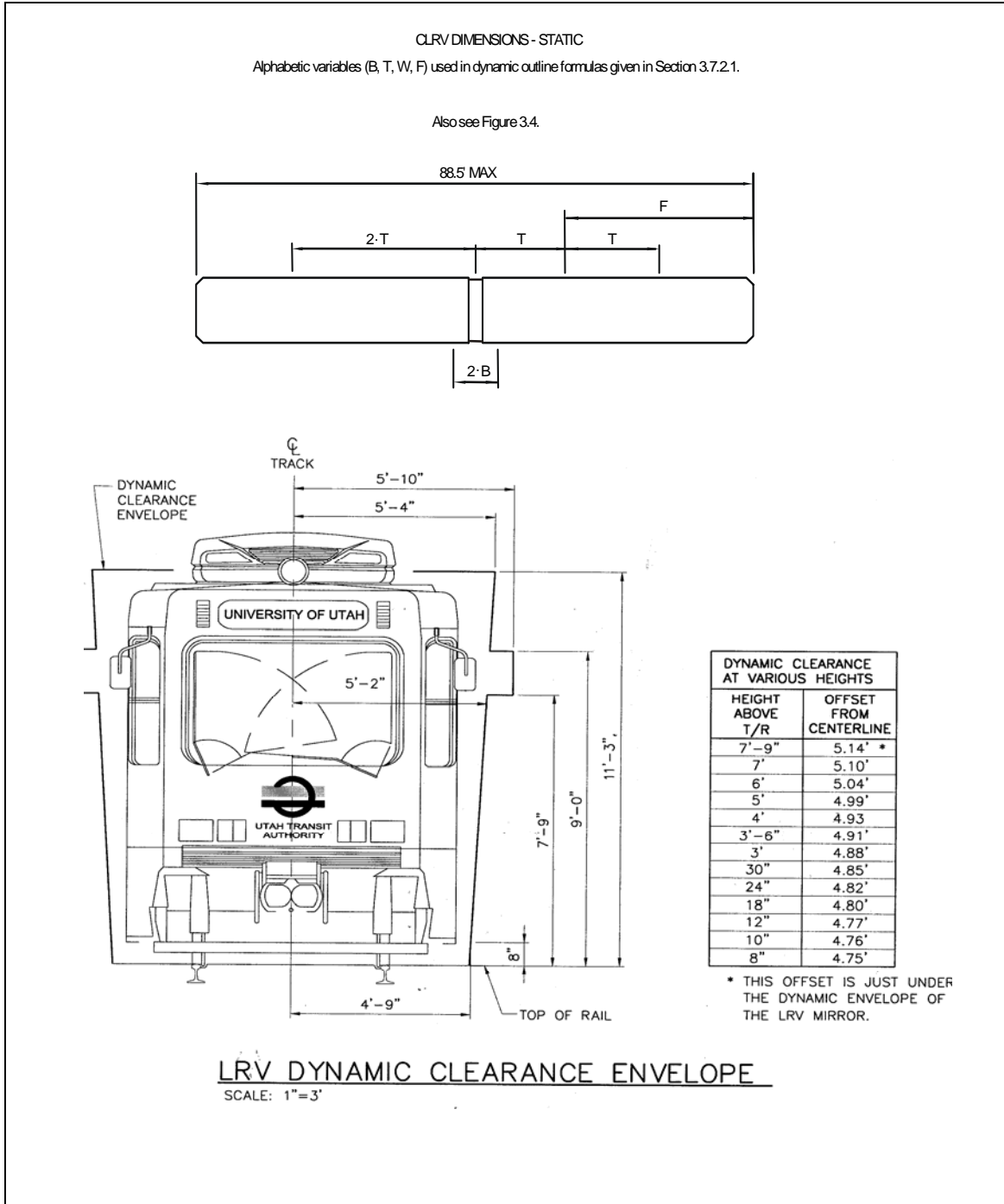
3.7.1 Vehicle Description

To allow the design of fixed facilities to proceed prior to the selection of a specific LRV, a composite design vehicle (CLR V) has been established based on the most critical vehicle dimensions and operational characteristics of the vehicles under consideration by UTA, and possible replacement vehicles in the future. The clearance criteria defined in this section is intended to provide latitude in selecting an LRV system for the present and for future selection of replacement vehicle technology.

3.7.1.1 Static Outline

The static dimensions of the composite LRV, as defined in Figure 3-1, include mirrors on each side and at the end of the LRV. The mirrors are assumed to be located typically from 7 feet to 10 feet above the top of rail and extend a maximum of 6 inches outside of the normal static vehicle envelope.

Figure 3-1: CLRV Static Dimensions and Dynamic Outline (Tangent Track)



3.7.1.2 Dynamic Outline

The dynamic outline of the composite LRV includes the anticipated dynamic movement of the vehicle during operation and factors to account for wear of both vehicle and track components during the life of the system. The major factors which affect the dynamic outline consist of the following:

- Lateral roll of the vehicle
- Primary and secondary suspension failure
- Vehicle body yaw
- Lateral play in the wheels
- Rail wear and wheel flange wear
- Vehicle manufacturer's tolerances

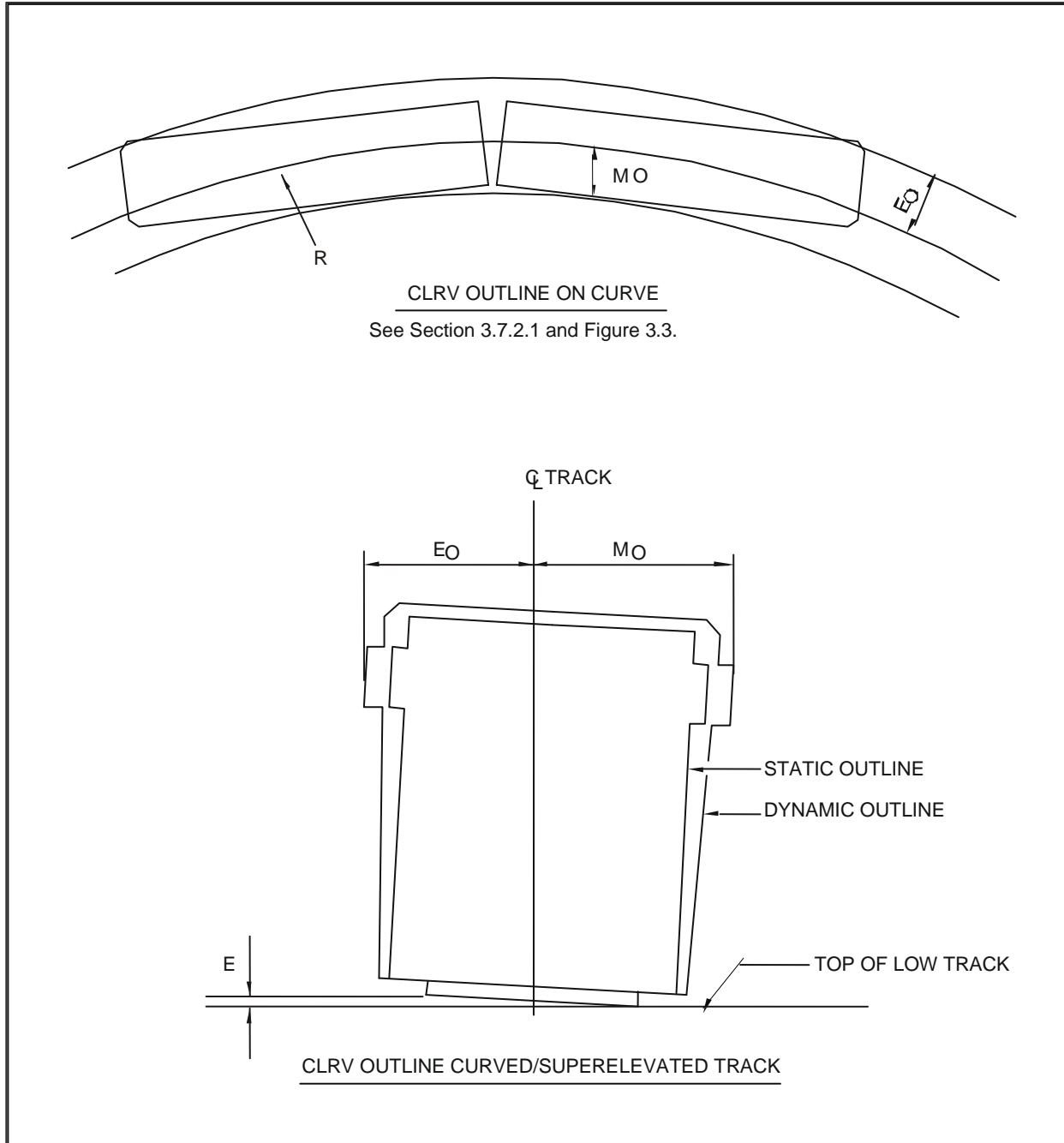
The actual extent to which these factors affect the total dynamic envelope are based on the specific vehicle selected and are only approximate. For design purposes, the total dynamic clearance from the static vehicle outline shall be assumed to be no less than 10 inches for the entire height of the vehicle.

The static and dynamic outlines of the composite LRV shown in Figure 3-1 shall be used as a basis for determining vehicle clearances to fixed facilities.

3.7.2 Track Curvature and Superelevation Adjustment

When a light rail vehicle enters a horizontal curve—including turnouts—the dynamic outline must be adjusted for overhang at the end of the vehicle and for middle ordinate shift (belly-in) midway between the trucks (bogies) of the vehicles. The presence of superelevation shall increase the middle ordinate shift particularly toward the top of the vehicle. See Figure 3-2.

Figure 3-2: CLRV Static/Dynamic Dimensions on Curved/Superelevated Track



3.7.2.1 Vehicle Middle Ordinate Shift Toward Curve Center

The middle ordinate shift of the CLRV toward the curve center shall be calculated by the formula:

$$MO = \{ R - (R^2 - B^2 - T^2)^{0.5} \} + W/2$$

where,

MO = distance from track centerline to vehicle middle ordinate, feet

R = centerline radius of curve

B = one-half of the vehicle wheel base, feet

T = one-half of the truck centers, feet

W = dynamic vehicle width without mirror envelope

MO shall be 5 to 10 feet minimum if radius is greater than 210 feet

Siemens,

B = 2.95 feet

T = 12.66 feet

F = 25.69 feet

UTDC,

B = 3.125 feet

T = 14.125 feet

F = 29.375 feet

3.7.2.2 Vehicle End Overhang Shift Away from Curve Center

The shift of the vehicle end overhang away from the curve center shall be calculated by the formula:

$$EO = [\{ (R^2 - B^2 - T^2)^{0.5} + W/2 \}^2 + F^2]^{0.5} - R$$

where,

EO = distance from track centerline to vehicle end overhang, feet

F = distance from the end of vehicle to center of two adjacent trucks, feet

W = dynamic vehicle width with mirror envelope

3.7.2.3 Vehicle Shifts Due to Superelevation

The distance from the centerline of track to the middle ordinate of the vehicle shall be increased where superelevation is applied in a curve. The maximum shift toward the curve centerline based on a desired distance H feet above the top of rail can be calculated by the formula:

$$X = 0.016 E H$$

where,

X = lateral shift due to superelevation, inches

E = actual superelevation, inches

H = height of point of analysis on vehicle

Figure 3-2 indicates how these dimensions relate to the CLRV.

3.7.2.4 Turnouts

When a light rail vehicle travels through the diverging route of a turnout the dynamic outline shall be affected. During final design, the dynamic outline shall be checked adjacent to, and 45 feet beyond, all curved components (switches, closure rails) of the diverging turnout route in order to determine potential conflicts with adjacent structures, poles, etc.

3.7.2.5 Mirrors

The CLRV shall include mirrors on each side toward the end of the vehicle. Mirrors are typically located 7–10 feet above top of rail, and extend 6 inches outside the edge of the vehicle.

For clearance requirements mirrors should be considered for tangent track and for the outside of all curves. Mirrors shall be considered for the inside of curves with a radius greater than 210 feet (middle ordinate shift shall govern for curves with radius less than 210 feet).

3.7.3 Horizontal Clearances

All existing and proposed structures, including catenary poles, bridge pier columns, and retaining walls shall clear the total LRV dynamic outline as defined in Section 3.7.2, by a distance equal to or greater than the sum of applicable clearances and tolerances defined in this section.

Clearances shall be checked between the LRV dynamic outline and all adjacent structures along tangent track and at turnouts a minimum of 50 feet in either direction of the structures. This is to verify that an adjacent curved track does not affect the clearance in the adjoining tangent section.

3.7.3.1 Track Spacing for LRT Exclusive Track

The minimum centerline to centerline distance between two tracks shall be 14 feet where there are center poles. Additional distance may be required when the tracks are curved or superelevated.

3.7.3.2 Clearance to Obstructions

The distance between any fixed object along the trackway and the centerline of track shall be equal the design envelope:

$$\text{design envelope*} = (\text{dynamic outline}) + (\text{running clearance}) + (\text{construction and maintenance tolerances})$$

NOTE: Acoustic treatment is part of structure. Allow 3" for acoustic treatment.

Exceptions to the design envelope requirements are listed in Section 3.7.3.7.

Figures 3-3 and 3-4 illustrate the required clearance envelope at station platforms.

Figure 3-3a: Freight and LRV Low-Center Platform Minimum Clearance Diagram

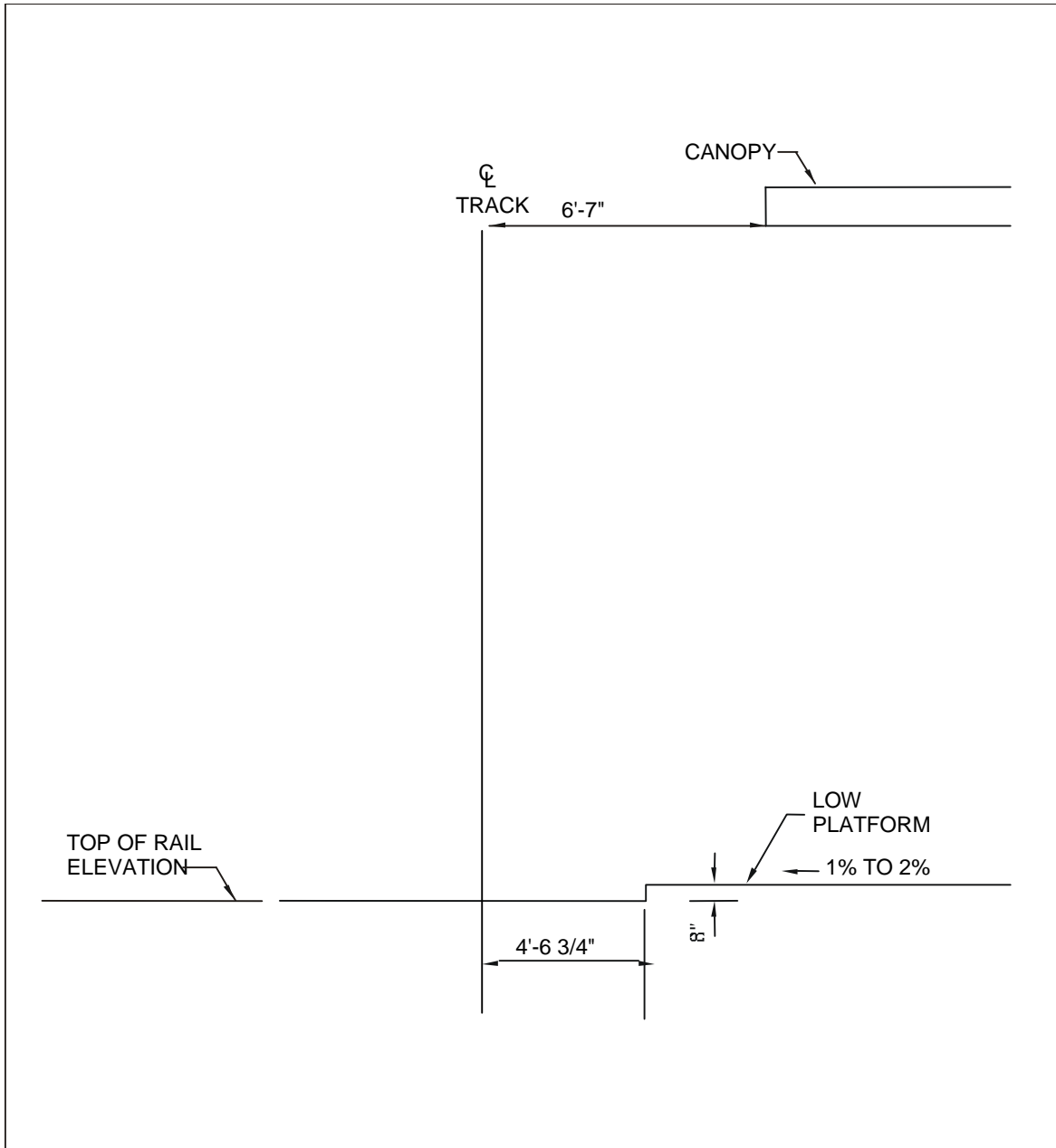


Figure 3-3b: LRV Only Low-Center Platform Minimum Clearance Diagram

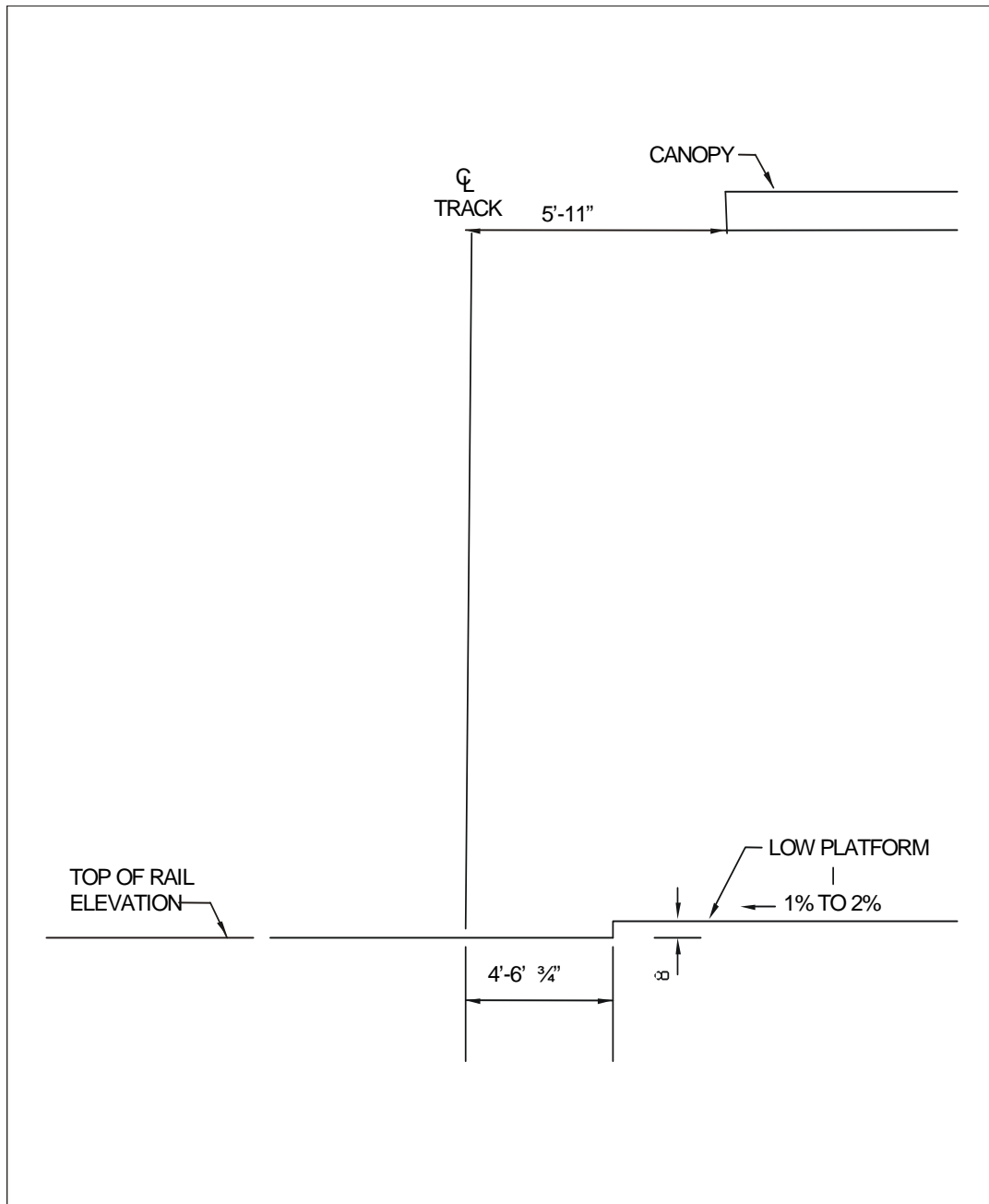


Figure 3-4a: Freight and LRV Mini-High Block Platform Minimum Clearance Diagram

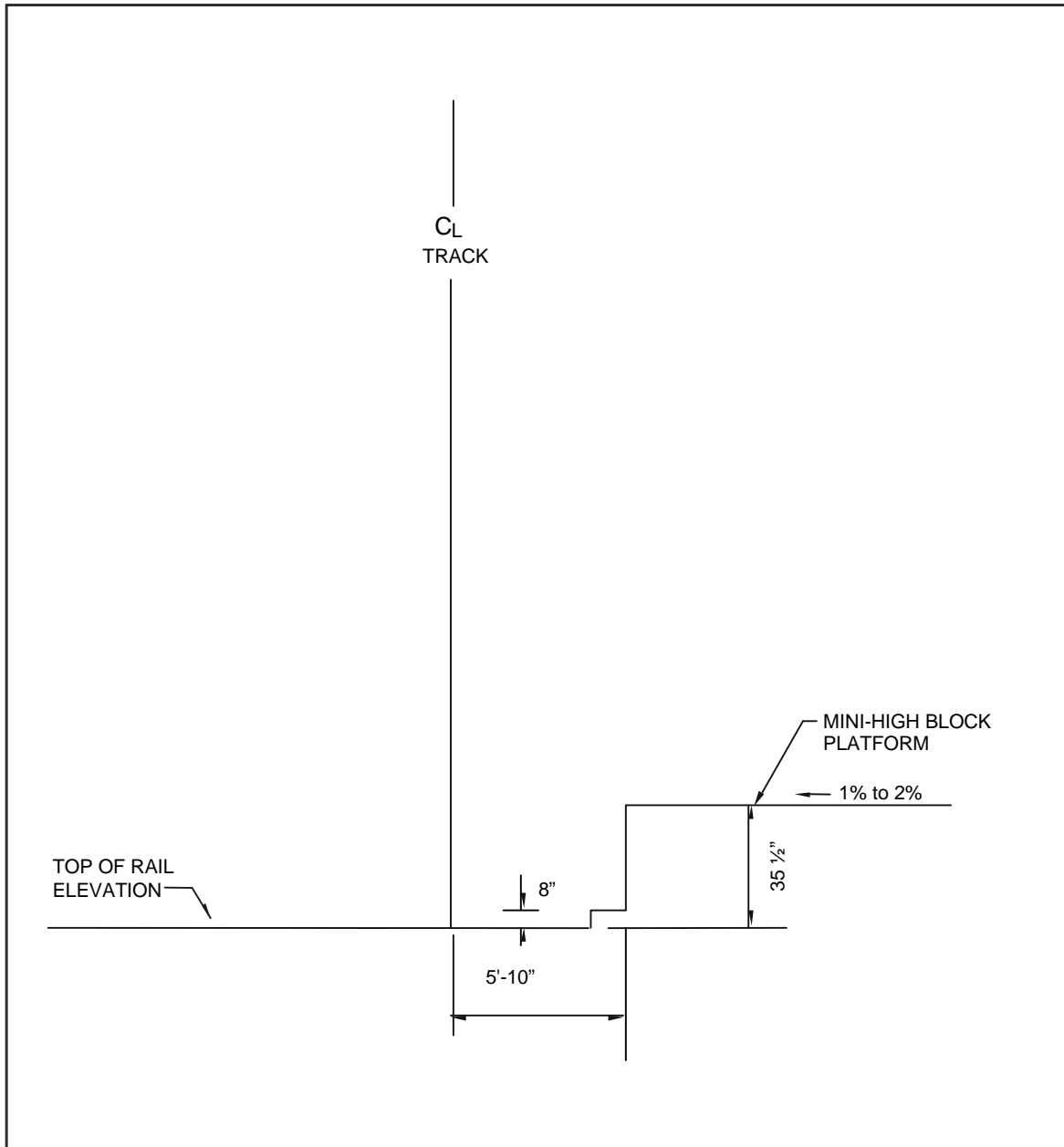
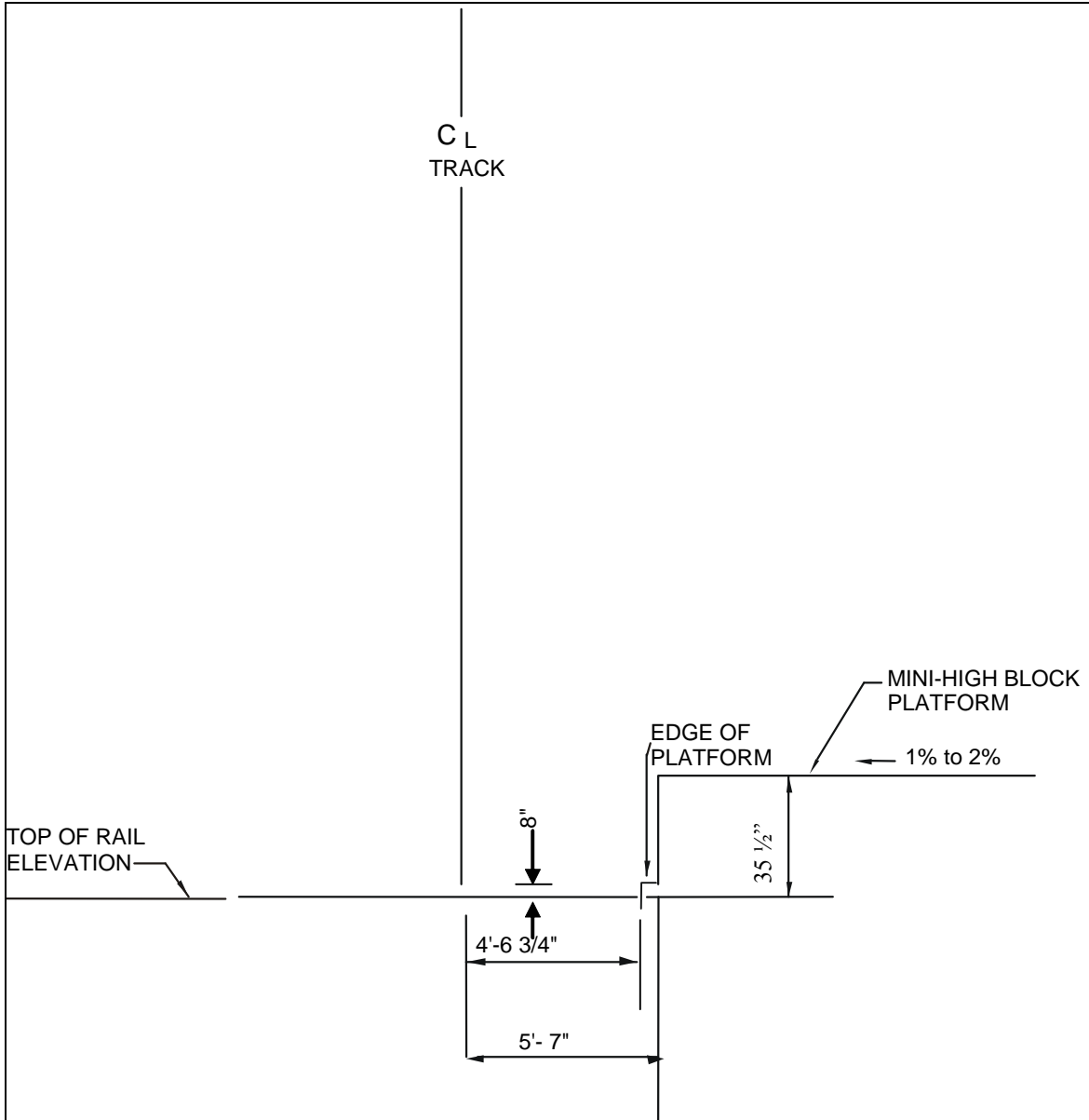


Figure 3-4b: LRV Only Mini-High Block Platform Minimum Clearance Diagram



3.7.3.3 Running Clearances

The running clearance provides clear passage for a vehicle which has moved to the extreme position within the dynamic outline. Design running clearances for exclusive LRT track shall be:

- 4" for poles and structural supports
- 2" for all other permanent structures

3.7.3.4 Construction Tolerances along Proposed Structures

A construction tolerance is required when a new structure is constructed adjacent to or above the LRT. This tolerance is added to the base construction and maintenance tolerance and applies to construction that is part of the LRT project or future construction. This construction tolerance is provided in the event that the structure, or part thereof, is mislocated during construction.

These clearances shall be:

- 6" for soldier pile and lagging walls
- 1" for other proposed structures

3.7.3.5 Track Construction and Maintenance Tolerances

Track construction and maintenance tolerances account for a combination of factors such as track misalignment, wheel and track gauge tolerances, and wheel and rail wear. These tolerances also include provision for any cross level variances between the track rails due to unintentional construction inaccuracies and possible deference of track maintenance during operation of the system. The following track construction and maintenance tolerances apply:

- Direct fixation or embedded track ½ inch
- Mainline tie and ballast track 3 inches
- Special track work ½ inch
- Yard track 3 inches

3.7.3.6 Horizontal Clearances for Joint Use Freight/LRT Tracks

This area outlines the following horizontal clearances for freight tracks:

- Centerline of adjacent railroad main track 18 feet min.
- To an obstruction on tangent 8 feet 6 inches
- To an obstruction on curve 10 feet preferred min.

Absolute minimum shall be determined based on overhand and middle ordinate shift calculations or the standards of the freight railroad involved.

- To property line or curb 12 feet preferred min.
- Fence of adjacent street 10 feet 6 inches min.

3.7.3.7 Exceptions to Design Envelope Clearances

All structures installed above the top of the nearest rail must be set either at or beyond the design envelope with the following exclusions:

- Retaining walls (see Section 3.7.3.8)
- Cut sections (see Section 3.7.3.8)

- Fill sections (see Section 3.7.3.8)
- Safety clearances (see Section 3.7.3.9)

3.7.3.8 Retaining Walls

Retaining walls shall comply with the minimum clearance requirements outlined below.

When a minimum clearance value is applied on one side of the track, a minimum shall not simultaneously be used on the other side of the track since a safe refuge area must be provided for passengers being evacuated from a train and for maintenance-of-way employees.

Additional clearances must be provided for installation of wayside signals where used. The civil and structural designers shall coordinate with the designers of the train control system so as to provide space for wayside signal equipment, to provide space for maintenance employees to service signal equipment, and to assure that train operators have a clear line of sight to signal indications at appropriate distances from the signal.

Cut Sections

The minimum clearance from the centerline of tangent track to the nearest face of the wall shall be the largest of the following:

- The dynamic envelope clearance
- 7 feet 1 inch for LRT exclusive track
- 8 feet 6 inches for joint use LRT/freight track

Fill Sections

The top of a retaining wall below track grade shall be at the same elevation as the top of the rail nearest to the wall. The clearance distance from the centerline of tangent track to the near face of the retaining wall shall be an absolute minimum of 6 feet (8 feet 6 inches for joint use).

3.7.3.9 Safety Clearances

Space shall be provided to allow for emergency evacuation of LRT passengers and provide an area for maintenance personnel to safely stand during passage of trains. This space should be provided in areas of restricted right-of-way, in areas of retained cut, and on structures. The space should be reasonably level and nominally 30 inches in width. The space shall be located to fulfill the following requirements:

- 30 inches of width beyond the static vehicle envelope
- 18 to 24 inches of width beyond the vehicle dynamic envelope

3.7.4 Vertical Clearances

The following minimum vertical clearances are required from the top of the high rail to the underside of any overhead structure, within the horizontal limits of the design envelope:

Trackway Environment	Minimum Height of Overhead Obstruction
Exclusive LRT track in dedicated rail corridor	18'-0" plus the depth of the catenary system ¹ , preferred
	15'-0" target minimum ²
	14'-3" absolute minimum ^{2,3}
Joint use LRT/freight track	22'-6" plus the depth of the catenary system ¹ , absolute minimum
LRT in street with mixed traffic in same lane or exclusive LRT being crossed by roadway at grade	18'-0" plus the depth of the catenary system ¹ , preferred minimum ⁴
	15'-0" plus the depth of the catenary system ¹ , absolute minimum ⁴

Notes

1. Depth of catenary system can vary depending on support system used. Coordinate with OCS designers.
2. Requires special OCS structures and may not be suitable for higher speeds. Coordinate with OCS designers.
3. LRV pantograph may be close to its "lockdown" height. Coordinate with vehicle designers and UTA vehicle maintenance staff.
4. Per the National Electrical Safety Code, the trolley contact wire must not be less than 18'-0" above the top of any roadway pavement under any condition of loading (including wind and ice loading) or temperature. Exceptions from the code must be obtained for any clearance less than that minimum.

END OF CHAPTER 3.



Utah Transit Authority Light Rail Design Criteria

Chapter 4 Track Work

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 4 TRACK WORK

4.1 General

The track work chapter provides details for the design and construction of the track work and its interface with other elements in UTA light rail projects.

Track work systems are composed of a number of elements, each of which has a definite interaction with other elements of the system. Because of this interaction, the design criteria for track work must be accomplished as a systems approach with a cause and effect analysis being undertaken on each of the elements. In performing this track work design, consideration of allied factors such as safety, stray current, noise, and vibration must be considered. In addition, the relationship of track work design to the design of other elements of the system, such as train control, traction power, drainage and the type of vehicle must be recognized and accommodated early in the design process.

Where the project interfaces with existing freight railroad trackage, the existing track work shall not be removed indiscriminately but only to facilitate new construction.

4.2 Track System

Three distinct types of track construction are encountered in the LRT system:

- Ballasted track
- Embedded track
- Direct fixation track

In addition, there are four possible conditions in the LRT corridor:

- Exclusive LRV corridor
- Joint use freight/LRV corridor
- Median running
- LRV running in-street with rubber-tire vehicles

The essential elements of track work shall include the following categories:

- Ballasted trackbed
- Embedded track structure
- Direct fixation track structure
- Rail
- Special track work
- Rail fastening systems
- Concrete ties
- Cross ties
- Other track materials (OTM)

The design of track work and its components shall include consideration of operations, maintainability, reliability, parts standardization and availability, capital costs, and maintenance costs. Track work shall be designed to suit the intended function for the proposed system operations. Maintainability and reliability considerations are important to minimize track downtime. Parts standardization and availability are important to allow minimization of track component inventories and to insure a reliable supply of parts.

4.3 Track Standards

In addition to the criteria and standards defined in this section, all track work shall comply with the minimum standards of the following:

- Utah Transit Authority (UTA)
- American Railway Engineering & Maintenance-of-Way Association (AREMA)
- Association of American Railroads (AAR)
- Federal Transit Administration (FTA)
- Federal Railroad Administration (FRA) (where applicable)
- American Public Transit Association (APTA)
- Union Internationale de Chemins de Fer (UIC; translation: International Union of Railways)—For any elements of track work that are fabricated or constructed in accordance with contemporary European railroad practice.
- Verband Deutscher Verkehrsunternehmen (VDV; translation: Union of German Transport Companies; formerly known as Verband Oeffentlicher Verkehrsbetriebe [VÖV]; Union of Public Transport Operations)—For any elements of track work that are fabricated or constructed in accordance with contemporary European transit practices.

The track work design shall be coordinated with and meet the requirements of system-wide corrosion control practices. Track shall therefore be designed to minimize stray currents resulting from the use of the running rail as the negative return conductor for the traction power current.

4.4 Track Construction Types

Track work shall be divided into the following three types of construction:

- Ballasted track—transit-only and transit plus freight railroad
- Embedded track (transit only)
- Direct fixation track (transit only and transit plus freight railroad)

Any of these types of track may include special track work and guarded track, as specified elsewhere in these criteria.

4.4.1 *Ballasted Track*

Ballasted track work shall be the standard for track work constructed at-grade. It shall also be used for track work on new bridges less than 350 feet in length when bounded on each end by open ballasted sections of track. Ballasted track, except as specified in these criteria, shall be constructed with continuous welded rail. See Figure 4-1 for typical section of ballasted double track in exclusive LRT and shared freight right-of-way. See Figure 4-2b for typical section of street-running LRT ballasted track. See Figure 4-2c for typical section of ballasted paved track. This track type might be utilized in a downtown

environment where the track is not subjected to automobile or truck traffic loads. This track type is not encouraged and is not considered a baseline standard on the UTA system.

4.4.2 Embedded Track

Embedded track construction shall be used where the LRV shares the trackway with rubber-tire vehicles along streets, street intersections, and at-grade crossings. Continuous welded rail (CWR) shall be used in embedded track sections. See Figure 4-2a for typical section of embedded double track.

The design of embedded track shall consider construction techniques to ensure that the track will be installed to proper gauge and alignment. The embedded track design also shall consider proper protection of rail and fastener components from exposure to storm water and corrosive elements, and shall allow for easy access to rail components for normal maintenance, repair, or replacement. The embedded track design shall address the following considerations:

- Rail section (tee rail or girder rail)
- Use of restraining rail in sharp radius curves
- Allowable vertical and lateral rail deflection (track resilience)
- Rail fastening system
- Drainage of rail fastener cavity or area
- Mass of embedment concrete required for vibration attenuation
- Electrical resistivity and insulation
- Compatibility of track paving material with thermal expansion of rail

At all interfaces between embedded track and ballasted track, a transition structure is required to accommodate the change in track modulus between the two systems.

4.4.3 Direct Fixation Track

Direct fixation track shall be used for track work construction on all bridges or aerial structures which are longer than 350 feet. Direct fixation track shall be designed for anchoring rail fasteners directly into a second pour concrete plinth or pad, constructed by either the bottom-up or top-down method. Concrete plinth or pad designs shall include sufficient anchoring to restrain the resultant rail and fastener forces.

Figure 4-1: Ballasted Double Track in Dedicated ROW

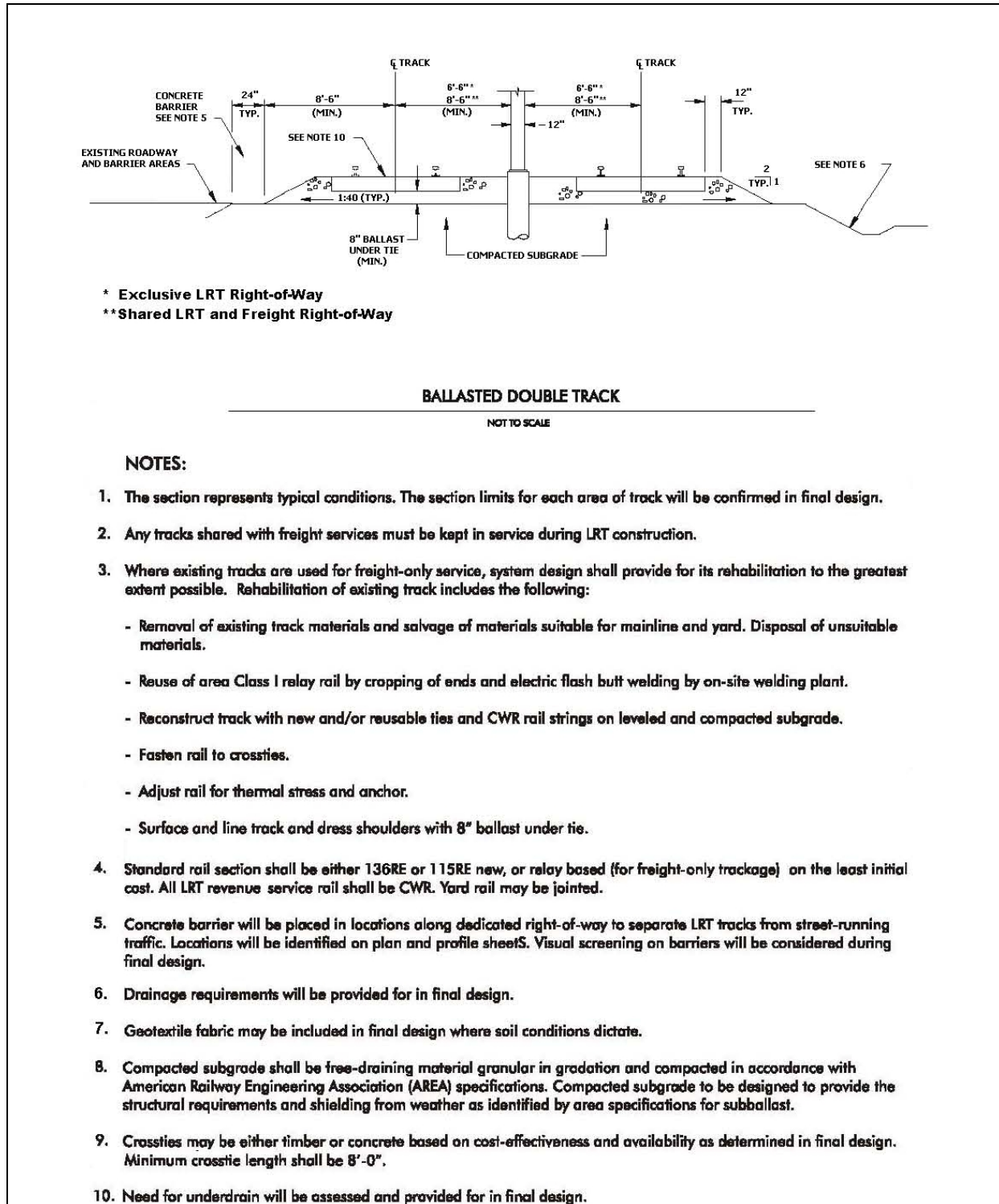
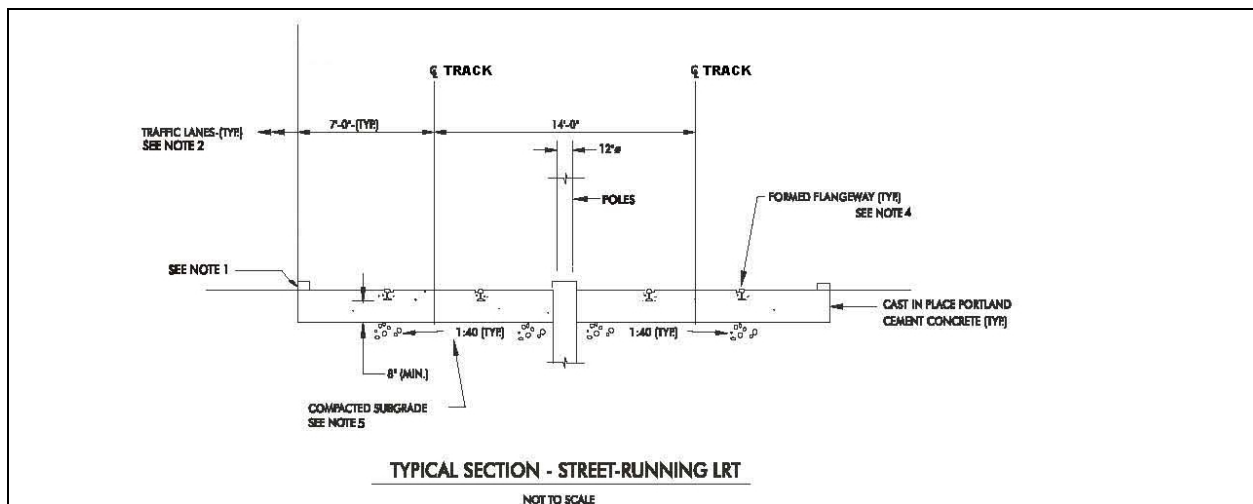


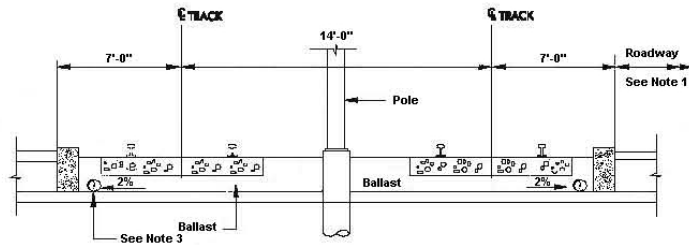
Figure 4-2a: Typical Section of Street-Running LRT



NOTES:

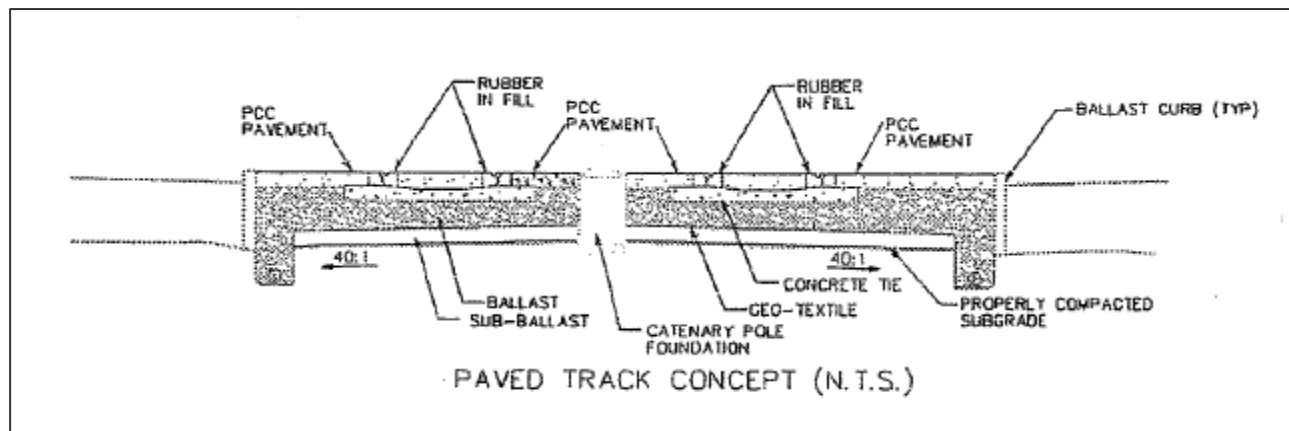
1. Concrete curb, per jurisdictional roadway requirements.
2. Asphaltic and/or Portland cement concrete pavement material to be placed and compacted consistent with local jurisdictional roadway pavement requirements.
3. Standard rail section shall be either 136RE or 115RE new, or relay-based on the least initial cost. All LRT revenue service rail shall be CWR. Yard rail may be jointed.
4. Flangeway to be formed in concrete.
5. Subgrade to be designed for concrete slab stability, control of differential settlement and consistent with utility protection requirements.
6. Drainage requirements will be provided for in final design.
7. Need for underdrain will be assessed and provided for in final design.
8. Jurisdictional restriction on construction sequencing to be considered in final design. Limits on periods of disruption may necessitate use of block outs for rails and second pour concrete or other compatible material.

Figure 4-2b: Typical Section of Street-Running LRT Ballasted Track



1. Ashaltic and/or Portland cement concrete pavement material to be placed and compacted consistent with local jurisdictional roadway pavement requirements.
2. Standard rail section shall be either 136RE or 115RE new, or relay-based on the least initial cost. All LRT revenue service rail shall be CWR.
3. Drainage requirements will be provided for in final design.

Figure 4-2c: Typical Section of Ballasted Paved Track



CWR shall be used on direct fixation track. Special consideration shall be given to the method of fixation of CWR to aerial structures so that longitudinal and lateral rail forces that are transmitted to the structure are not applied in a manner that could damage the structure.

At all interfaces between direct fixation track and ballasted track, a transition structure is required to accommodate the change in track modulus (track stiffness) between the two systems.

4.4.3.1 Rail Fastener

The direct fixation fastener design shall include the following considerations:

- Type of fastener: spring clip or clamp, or threaded fastener
- Spring stiffness for noise and vibration control
- Longitudinal restraint (fastener slip)
- Rail cant
- Type of anchor bolt assembly
- Vertical and lateral adjustment capability
- Electrical resistivity and insulation properties

4.4.3.2 Concrete Plinth or Pad

The design of the supporting concrete plinth or pad shall include the following considerations:

- Plinth or pad dimensions to suit track alignment and to accommodate restraining rail and/or emergency guardrail where required
- Interface connection of plinth or pad with elevated structure deck
- Anchoring to restrain resultant rail forces
- Elevated structure and rail interaction
- Drainage of plinths or pads on elevated structure deck

4.5 Track Gauge

Track gauge shall be the standard gauge of 4'-8½", measured between the inner (gauge) sides of the heads of the rails at a distance of ⅝" below the top of the rails. Wider gauges shall be used in some curves, depending upon the radius. Gauge of curves shall be as follows:

- Tangent track and curves with radii equal to or greater than 280': 4'-8½"
- Curves with radii smaller than 280' but larger than 200': 4'-8¾"
- Curves with radii smaller than 200' but equal to or larger than 82': 4'-9"

Gauge widening shall be at a rate of not more than ¼ inch in a distance of 62 feet. Full gauge widening shall be accomplished on the tangent in approach to the point of curve and removed following the point of tangent in unspiraled curves. In spiraled curves, gauge widening shall be applied and removed over the length of the spirals. If the spiral is too short for full gauge widening to be accomplished without the rate exceeding ¼ inch in 62 feet, sufficient gauge widening shall be placed in the approach tangents to meet the rate of ¼ inch in 62 feet. If adjacent curves requiring widening are too close together to allow run out of the gauge widening, the widened gauge shall be maintained between the curves.

Where widened track gauge is used, the designer shall determine the appropriate flangeway width dimensions for guarded track and for open flangeways in paved track.

4.6 Wheel Profile and Gauge

The wheels shall conform to the standard Association of American Railroads (AAR) Mechanical Division wheel standards for a Type 1B "worn wheel" with a wheel gauge of 4'-7 31/32".

4.7 Track Construction Tolerances

Track construction tolerances are determined by taking safety, speed of operation, and the type of service to be provided into consideration (see Table 4-1.)

Table 4-1: Track Construction Tolerances

<i>Type of Track</i>	<i>Track Gauge Deviation</i>	<i>Cross Level and Super-elevation Deviation</i>	<i>Vertical Track Alignment</i>		<i>Horizontal Track Alignment</i>	
			<i>Total Deviation</i>	<i>Middle Ordinate in 62' Chord</i>	<i>Total Deviation</i>	<i>Middle Ordinate in 62' Chord</i>
Mainline Ballasted Track	+/- ⅛"	+/- ⅛"	+/- ¼"	+/- ⅛"	+/- ½"	+/- ⅛"
Mainline Ballastless Track	+/- ⅛"	+/- ⅛"	+/- ¼"	+/- ⅛"	+/- ½"	+/- ⅛"
Yard Ballasted Track	+/- 3/16"	+/- ⅛"	+/- ½"	+/- ¼"	+/- ½"	+/- ¼"

Notes: (1) Rate of change in vertical and horizontal alignment (direction) shall not exceed ⅛" per 31' of track.

- (2) Total deviation is measured between the theoretical and actual alignment at any point in the track. Total horizontal deviation in station areas shall be plus 3", minus 0 measured from edge of platform.

Permissible deviation from the established values must be approved by the UTA Light Rail Transit Director. The deviations shall be clearly specified in design and construction documents and enforced during construction.

In addition, the design should be prepared to provide UTA guidance regarding maintenance of the designed track components. This guidance should include the items listed earlier plus allowable wear limits and allowable movements of the various components of the track structure.

4.8 Traction Power—Impact on Track

The purpose of the power distribution system is to conduct current from the substation to the vehicle pantograph and return the current to the substation. The system includes all positive power cable, overhead catenary, the negative return system, and various disconnecting devices, all located outside of the substation. The negative return system usually consists of one or more running rails, reinforced by means of negative paralleling cables if required.

All rail joints (except for insulated joints and head bonds) and electrical track connections must be electrically bonded. Exothermic cadwelds at these joints or connections are prohibited. Cables shall be through bolted to web of the rail per AREMA.

Appropriate measures shall be taken during the design of all types of track work, including embedded track and highway grade crossings, to minimize the leakage of stray negative return current from the track structure to the ground. This work shall be consistent with system corrosion control requirements.

Traction power requirements pertinent to track installation shall be indicated on track work drawings as a reference.

4.9 Signaling and Train Control Impact on Track

Light rail may include both track circuits and wayside inductive loop detector systems to suit both ballasted and embedded track zones respectively. Impedance bond installation areas and requirements must be coordinated with the track structure. Insulated joints at limits of track circuits are to be opposite each other (with minimal stagger) to facilitate underground ducting and traction crossbonding. See Chapter 13 of this manual for additional information.

Signaling and train control requirements pertinent to track installation shall be indicated on track work drawings as a reference.

4.10 Ballast, Subballast, and Subgrade

The design of the ballasted track section shall ensure an adequate foundation for minimization of system maintenance requirements. The trackbed foundation and ballasted sections shall be designed to fit within the allotted corridor width and to provide a uniform, well-drained foundation for the track structure.

The ballast section design shall include analysis of the pressures exerted on the ballast elements due to the rail forces transmitted by the LRV or freight vehicle. These forces shall be calculated based on the gross

dynamic wheel load of the LRV or freight car, track modulus, effective bearing area of cross tie, and assumed soil bearing capacity of the subgrade as defined herein. The minimum ballast depth shall be determined by the formula:

$$D_{\text{BALLAST}} = [16.8 P_A / P_C]^{0.80} \text{ (Reference: AREMA 2.11.2.3.b)}$$

where,

D_{BALLAST} = minimum ballast depth, inches

P_A = maximum allowable tie load (85 psi concrete ties, 65 psi wood ties)

P_C = soil bearing pressure, psi

4.10.1 Subgrade

The subgrade is the finished surface of the ballasted track foundation and is required to provide uniform strength and stability. The ballast section shall be designed based on a maximum acceptable bearing pressure on the subgrade soil of 25 psi. The actual soil bearing capacity of the existing ground surface shall be determined by geotechnical testing to verify the actual soil bearing pressure. Where testing reveals that the actual capacity is less than 25 psi, the contractor's engineer shall either design a track structure that will not overstress the existing soils or recommend a treatment of the subgrade soils to achieve the minimum capacity cited above.

Access to the track from adjacent roadways shall be provided at strategic locations for both rubber-tired emergency vehicles and for UTA maintenance-of-way vehicles including "hy-rail" vehicles with flanged wheels for driving on the track. Where practicable, the access point shall provide a turn-around.

4.10.2 Subballast

A subballast layer consisting of a well graded and compacted aggregate shall be placed on top of the finished subgrade in accordance with the dimensions shown on the ballasted track typical section. This layer can be included as part of the overall ballast depth required for the given loads and subgrade bearing pressure. The required gradation of the subballast layer shall be defined in the specifications.

4.10.3 Ballast

Ballast is a selected crushed and graded hard aggregate material placed upon the subballast to provide support for the rail and ties and to distribute the track loadings to the subgrade. AREMA states ballast (plus subballast) must be of sufficient depth to distribute pressure between tie and subgrade. Ideal tie to ballast bearing pressures are 65 psi for timber ties and 85 psi for concrete ties. The ballast must sustain and transmit static and dynamic loads in three directions (transverse, vertical, and longitudinal), distributing them uniformly over the subgrade. A major function of the ballast is to drain the track system. The ballast holds the track in proper alignment, cross slope, and grade, and permits adjustment and revision of these features. The gradation must provide the means to develop the stability and density requirements for the ballast section and provide necessary void space to allow proper run off of groundwater. Existing track embankments should be investigated to determine conditions and soundness for reuse.

Ballast gradation shall conform to AREMA size #4. In the yard area and industry spurs, AREMA size 4A ballast may be used.

4.11 Concrete Ties, Timber Crossties, and Timber Switch Ties

Concrete ties shall be used on ballasted track sections along the mainline and yard tracks, except at special track work. Concrete ties may be used at special track work if cost effective.

Concrete ties shall consist of prestressed monoblock concrete tie designed in accordance with the AREMA *Manual for Railway Engineering*, Chapter 10 “Concrete Ties,” and current ACI 318 design procedures. In addition to inserts for traffic rail fastening clips, concrete ties shall be designed with anchorage points for restraining rail and/or emergency guardrail as may be required. Rail seat areas shall be canted at 1:40. The rail clip design shall provide proper longitudinal and lateral restraint to the welded rail and also incorporate electrical insulating elements so as to minimize the transmission of stray traction power currents and assure the proper operation of signal system track circuits.

The concrete tie design shall address the following considerations:

- Rail seat positive and negative loads
- Tie center negative load
- Prestressing tendon bonding strength
- Compressive strength of concrete at 28 days
- Prestressing steel strength
- Result in an acceptable tie bearing pressure on the ballast assuming that track loading is applied to not more than $\frac{2}{3}$ of the tie’s footprint
- Electrical isolation of the rails from ground and from each other

4.11.1 Timber Ties

Timber ties shall be used where appropriate on ballasted track sections at special track work and along freight railroad industrial spurs. Timber ties may be used in mainline and yard track sections if required for specific purposes where concrete ties are impractical.

Timber ties shall consist of “7-inch grade” ties meeting the requirements of the AREMA *Manual for Railway Engineering*, Chapter 3 “Ties and Wood Preservation,” and the specifications of the Railway Tie Association and the American Wood Preservation Association.

Timber tie design shall address the following considerations:

- Rail seat positive and negative loads
- Tie center negative load resulting in an acceptable tie bearing pressure on the ballast assuming that track loading is applied to not more than $\frac{2}{3}$ of the tie’s footprint
- Wood species and preservation method
- Electrical isolation of the rails from ground and from each other, where required

Second hand “relay grade” timber ties that have been salvaged from existing tracks and rehabilitated by plugging and preservative treatment of the tie plate seat area are acceptable for LRT yards and railroad freight spurs provided that they are in such condition that they can reasonably be expected to provide another 15 to 20 years of service. No more than 50% of the ties in any tangent track may be rehabilitated relay grade ties. Lesser percentages may be used in curved tracks with a maximum of 25% relay grade ties in curves of the minimum radius for each particular class of track. The percentages of relay grade ties

used in curves of intermediate radius shall be proportional to the percentages above based on the degree of curve—Da. Relay grade ties shall not be used beneath bolted rail joints or other locations of higher stress.

4.11.2 Switch Ties

Switch ties for special track work in ballasted sections shall consist of either concrete or timber ties produced from durable hardwoods such as beech, birch, hard maple, ash, and oak and designed to the standards for timber ties defined above. Tropical hardwoods such as azobe that are often used without preservative treatment may be used with the approval of the UTA. The timber sizes and spacings shall vary as required to provide continuous support between tracks at turnouts and crossovers.

Switch tie spacing in special track work should meet the requirements of the specific turnout geometry. Switch tie lengths shall be selected such that no tie is spiked within 12 inches of its end. Interwoven switch ties are not acceptable and switch ties longer than 16 feet shall be provided where necessary to avoid interwoven ties and to avoid spiking ties too close to the tie ends.

4.12 Running Rail

The standard 115 RE rail section shall be used for all track sections except in joint operation freight/LRT corridors or in freight-only tracks. In tracks used by freight railroads the rail section selected shall be as approved by the rail freight operator. Where freight railroad operations share tracks with LRT, a rail section heavier than UTA's standard 115 RE section that has a moment of inertia not less than 85 in⁴ shall be used. In any such case, the Union Pacific standard 133 RE rail section shall be used whenever possible so as to minimize UTA maintenance inventories. Exceptions will be allowed only in the event that a different rail section is required by the railroad freight operator. Each such case shall be justified and submitted to UTA for acceptance.

All new rail shall meet the current requirements of the AREMA *Manual for Railway Engineering*, Chapter 4 "Rail" for steel tee rail.

Second hand rail that meets the AREMA classifications for No. 1 relay rail may be used in LRT yard tracks and railroad freight industrial spurs. Any such rail used in UTA tracks that are not used for freight operations should be one of the following sections: 112 RE, 115 RE, or 119 RE.

All running rails in track used for LRT operations shall have joints between adjoining rails welded by either the flash butt pressure welding method or the exothermic thermite method. Rails shall be shop welded by the flash butt welding process into the longest lengths feasible for delivery to the site and installation. Thermite rail welding shall only be used to connect contiguous CWR strings and to weld in shop curved rails and in special track work locations where flash butt welding is impractical.

All running rail shall be surface ground to remove all small imperfections and to mill any scale prior to track being used for service. This procedure is required to help prolong the life cycle of the rail and to promote a smooth and quiet riding surface.

All rails on curves with a radius less than 300 feet shall be pre-curved in a shop using either roller bending or gag-press methods. Joints in pre-curved rails shall be by either thermite welding or bonded joint bars.

4.12.1 Standard Carbon Steel Rail

Running rails on all primary tracks shall be standard carbon steel rails, minimum 300 Brinell hardness, manufactured in accordance with the latest edition of the AREMA *Manual for Railway Engineering*, Chapter 4 “Rail.”

4.12.2 High Strength Rail

High strength rail shall be used at all areas anticipated to have a high frequency of acceleration and braking, on steep grades 5% or greater, throughout special track work limits, and in mainline track curves with radii of 900 feet or less. This includes the full length of the track at the platforms, plus 45 feet at either end of the platform. High strength rail shall be head hardened.

Where high strength rail is used in circular curves with spirals, the high strength rail shall, at a minimum, extend from the point of tangent-to-spiral to the point of spiral-to-tangent. In the case of spirals with lengths that are less than 32 feet, the high strength rail shall continue into the tangent track as distance that is the greater of those determined from the following:

- No less than 32 feet from the point of spiral-to-curve or curve-to-spiral
- No less than 32 feet from the point where the instantaneous radius of the clothoid spiral is equal to 300 feet

Where high strength rail is used in two sections of track connected by a section with standard rails spaced less than 150 feet, high strength rail shall be used continuously through the connecting section.

4.12.3 Continuous Welded Rail

All mainline track shall be designed to use continuous welded rail wherever possible. The resulting spacing of rail fasteners on embedded and direct fixation track, and tie spacing on ballasted track shall be designed based on principles of continuous welded rail forces as described herein.

4.12.3.1 Rail Deflection

Rail deflection shall be limited to 1/8 inch based on the maximum of the deflection value calculated based on a single wheel and a two wheel load.

Maximum deflection shall be calculated by the formula:

$$Y_o = P / (64 E I \mu^3)^{0.25}$$

where,

Y_o = Maximum deflection, inches

P = Dynamic wheel load, pounds

E = Modulus of elasticity of rail steel (30 × 10⁶ psi)

I = Moment of inertia of specified rail section (in⁴)

μ = Track modulus

The track modulus shall be approximated based on a static condition by the formula:

$$\mu = \text{fastener spring stiffness (lbs/in)} / \text{fastener spacing (in)}$$

4.12.3.2 Maximum Bending Stress

The maximum bending stress in the rail shall not exceed 25,000 psi, based on the yield point of rail steel of 70,000 psi. The bending stress shall be calculated by the formula:

$$S_b = M_o c / I$$

S_b = Maximum bending stress, psi

where,

$$M_o = P (E I / 64 \mu)^{0.25} \text{ (maximum bending moment)}$$

P = Dynamic wheel load, pounds

E = Modulus of elasticity of rail steel ($30 \times 10^6 / \text{in}^2$)

I = Moment of inertia of specified rail section (in^4)

μ = Track modulus

c = Distance from rail base to neutral axis, inches

4.12.3.3 Axial Tensile and Compressive Forces

The maximum axial tensile force shall be calculated based on the maximum expected temperature drop of the rail below the zero thermal stress temperature. The maximum axial compressive force shall be calculated based on the maximum expected temperature rise of the rail above the zero thermal stress temperature. Allowance should be made for a zero thermal stress tolerance of plus or minus 10 °F. Additional consideration shall be made regarding the magnitude of axial forces due to acceleration and braking.

4.12.3.4 Rail Break Forces

Broken rail forces are those forces which are transferred to the structure in longitudinal shear by the rail fasteners when a rail break or pull-apart occurs. The pull-apart force is resisted both by the structure frame and the unbroken rails on the structure. The distribution of the broken rail forces onto the structure are site and structure specific. The most probable location of a rail break, other than at weld locations, is in the vicinity of an expansion joint of the supporting structure, since the tensile stress of the rail is at its maximum at this location. After a rail break occurs, the rails adjacent to the point of break will move apart creating a gap until the cumulative restraints developed by the rail fasteners are large enough to resist further movement. As the rail slides through the fasteners, the force in the rail near the point of rail break reduces to zero. The forces in both the rail and structure then will increase as the rail continues to translate until maximum longitudinal restraint is achieved. The resulting rail pull apart gap and forces shall be calculated based on extreme conditions with the maximum temperature drop and the lowest restraint capabilities of the fastener.

In curved track sections, the lateral deflection of a broken rail due to centrifugal force of the vehicle shall be considered in determining the minimum required spacing of the fasteners in curves. A maximum offset of 1/8 inch is considered to be the allowable safe limit for a rail break, based on the calculated deflection due to application of the lateral wheel load on the free bending of non-precurved rail.

In applying the restraint loads to the rail and structure, it is important to note that the sum of all restraint forces within the region of rail movement should be applied to the structure in the broken rail analysis. The unbalanced force from the broken rail is resisted by both the unbroken rails and the guideway support system in proportion to their relative stiffness. It is also important to consider the twisting forces and lateral created by broken rail conditions.

4.12.3.5 Unbalanced Thermal Forces at Special Track Work

Unbalanced rail thermal forces exist in special track work locations due to the discontinuities in the rail. Standard turnout units are not designed to transfer high rail forces through the units in aerial structures without causing misalignment and its consequent wear and tear. The direct fixation track design shall include a proposed method of creating a zero force condition through the special track work unit by dissipating the rail forces into the superstructure.

Consequently, the substructure will need to be designed to compensate for these induced forces and the design shall consider the following:

- The special track work units within the limits of the elevated structure will move with the structure. When the structure moves, it is assumed that the special track work will move relative to the structure and that internal stresses developed within the special track work will be accommodated by the use of anti-creep devices in the baseplates of the special track work.
- The special track work units shall be positioned at the mid-span of the frame structure and away from structural expansion joints to reduce the amount of stresses induced into the structure when it expands or contracts. The structure shall consist of a continuous span structure, where practicable.

4.13 Use of Rails and Other Track Material from Existing Tracks

Some of the existing rail can be used for freight-only uses including sidings, tie-ins, and yard and team tracks. All reused rail should conform to AREMA standards for #1 grade relay rail.

4.14 Restraining Rail and Strap Guard for Curved Track

All track having a centerline radius of less than or equal to 300 feet shall have restraining rail added to the inside running rail to reduce rail wear on the outside rail. This reduced wear results from the division of lateral loads between the high rail of the curve and the working face of the restraining rail. Restraining rails also reduce the possibility of derailments attributable to the leading outside wheel climbing the outside rail since the assumption of some lateral load by the restraining rail reduces the lateral load/vertical load ratio. Restraining rail shall also be considered for any track where there is a possibility that the unbalanced superelevation U may be greater than 4 inches under reasonably expected operations.

Restraining rail shall normally be vertically mounted tee rail that has been pre-curved and pre-drilled for installation at a specific location. Assembly to the matching CWR may either be made in the fabricating shop or by field fitting with running rail that is drilled in the field.

On circular curves with spirals, the restraining rail assembly shall extend at least from the point of tangent to spiral to the point of spiral to tangent. In the case of spirals with lengths that are less than 32 feet, the restraining rail shall continue into tangent track a distance that is the greater of those determined from the following:

- No less than 32 feet from the point of spiral to curve or point of curve to spiral
- No less than 32 feet from the point where the instantaneous radius along the spiral is equal to 300 feet

The flared flangeway area at the end of a segment of restraining rail shall not be counted as an effective segment of restraining rail in the determination of the requisite overall length of restraining rail to be

used. Flared portions of the restraining rail flangeway shall be at least as long in inches as the allowable track speed in miles per hour with a minimum flare length of 12 inches.

4.15 Emergency Guardrail

Emergency guardrail shall be used to restrain the lateral movement of derailed rail vehicle trucks on all bridges, retained fills and their approaches, and other locations where the result of a derailment could be particularly catastrophic. Emergency guardrail is not required in either paved track areas or in locations where it would interfere with special track work features.

Emergency guardrail shall ordinarily be fabricated from used rail and installed in accordance with the Standard Drawings. In direct fixation track and other locations where advantageous, emergency guardrail may be fabricated from a structural angle or tee section of appropriate size.

On single track structures or for a single track located on retained fill, guardrail shall be installed adjoining both running rails. For double track, one guardrail is required for each track and it shall be located inside the running rail which is farthest from the edge of the structure or retaining wall. For more than two tracks, guardrail shall be installed on the track(s) nearest to the edge(s) of the structure.

The rail shall be installed inside the running rail which is furthest from the edge of the structure. On main tracks, the guardrail shall extend 100 feet ahead of the beginning of the bridge structure or area being protected on the approach end. The guardrail shall extend 50 feet beyond the end of the protected structure on the departure end, and 100 feet beyond each end on bi-directional tracks. Guardrail extensions may be one-half these distances on tracks operated at 20 mph or less.

4.16 Tie Plates for Timber Ties

If timber ties are used for LRT revenue track an elastic fastening system shall be used that shall provide sufficient longitudinal restraint to preclude the use of rail anchors. Tie plates shall be secured to the cross ties with either lag screws or lock spikes. To deter the transmission of stray currents to the ballast section, no metallic portion of the rail fastener shall extend below the elevation of the top of tie.

The standard rail fastening for timber ties in freight-only track shall consist of standard AREMA tie plates with cut spikes and rail anchors. This fastening system may be used in LRT yard track provided that corrosion control studies document that the traction power system for the yard can be grounded.

4.17 Special Track Work Plates for Timber Switch Ties

Ballasted special track work for mainline alignments shall be insulated plate equipped with elastic rail clips so as to provide stray current isolation in accordance with the criteria determined by the traction power and stray current engineers.

4.18 Insulated Joint Bars

Insulated joints shall be provided wherever required for proper operation of the signaling system or where required to isolate one section of track from the traction power negative return circuit.

Where insulated joints are provided for signaling purposes, the signaling system shall include impedance bonds to provide a continuous path for traction negative power return current. See Chapter 13 for impedance bond requirements.

All insulated joints should be located as suspended joints to obviate the need for insulated tie plates, a high maintenance item.

4.18.1 Continuous Welded Rail

Insulated joint bars of the epoxy bonded type shall be used in CWR wherever it is necessary to electrically isolate contiguous rails from each other in order to comply with track signaling or traction power criteria. Track bolts shall be equipped with self-locking nuts.

Insulated joint bars shall also comply with the physical parameters listed in Section 4.20 of these criteria.

4.18.2 Jointed Rail

Wherever insulated joint bars are required in track constructed with jointed rail, or where insulated joints are required in a traffic rail equipped with restraining rail, they shall be polyurethane encapsulated bolted insulated joints.

4.19 Bonded Joint Bars

Except in those tracks designated as being constructed with jointed rail, bolted joints shall only be used between welded rail strings of different chemical composition or metallurgy. These joints shall be of the epoxy bonded type and shall be fastened with high strength bolts. Such joints shall be electrically bonded to provide a continuous path for traction power negative return current and signal circuits. They shall comply with the following parameters:

- Identical drilling pattern as standard joint bar
- Compatible with the standard direct fixation rail fasteners
- Comply with the general requirements of a rail joint as defined by the *AREMA Manual for Railway Engineering*

Flash butt welds shall be used wherever possible to join rail of different chemical composition or metallurgy.

4.20 Joint Bars

The use of bolted joints shall be minimized during design except in those locations where the use of jointed rail is specified. These joint bars shall be standard AREMA 36-inch six-hole for main track and 24-inch four-hole for secondary and yard track. Track bolts, nuts and lock washers shall conform to AREMA standards.

4.21 Compromise Joint Bars

Compromise joint bars shall be used to connect rails of dissimilar section wherever field welding is infeasible or where the connection is temporary in nature. Wherever possible, however, field welds of the thermit type shall be used to connect dissimilar rail section for permanent connections.

4.22 Derails

Sliding derails shall be used to prevent out-of-control railroad freight cars or transit vehicles from fouling adjoining or adjacent tracks. Derails should be installed on the downgrade end of yard and secondary

track normally used for the storage of unattended LRVs if this track is directly connected to the mainline track and if its prevailing grade is descending toward the mainline track.

Derails shall be placed at the 14'-0" clearance point of all railroad industry tracks which connect to the main track on a downgrade. Derails shall be used at other track locations where they would be likely to prevent or minimize injury to passengers and personnel and/or damage to equipment.

Derail shall be located so as to derail equipment in the direction away from the main track.

4.23 Special Track Work

The term "special track work" designates the track work units necessary where tracks converge, diverge, or cross one another. Special track work includes turnouts, crossings, and crossovers, singly or in combination. All special work design shall be based on AREMA standards except as modified to meet the special conditions.

All special track work shall be designed and constructed in accordance with the UTA Reference Drawings. Standard turnouts and crossovers shall be located in ballasted track only. Embedded special track work shall be of special design to suit the location and in accordance to Standard Drawings.

The limits of any track work design or construction unit shall not be located within a special track work unit.

Special track work shall be located in tangent horizontal track, except that with prior approval, special track work may be located in a horizontal curve. There shall be no superelevation in any special track work units. All special track work shall be located on tangent vertical profile grades.

Special track work should not be located within 250 feet of a transition between track types without approval of the UTA Light Rail Project Director. The minimum length of horizontal tangent track between any point of switch and the end of the ultimate four-car station platform shall be:

- 60 feet for exclusive LRT track
- 60 feet for combined LRT/freight traffic

The horizontal and vertical alignment adjacent to special track work shall conform to the separation distances required between points of intersection of various combinations and directions of turnouts and curves as shown in Table 4-2.

Table 4-2: Minimum Distances from Turnout P.I. to the Beginning of Horizontal or Vertical Curves

<i>Facing End (Switch Points)</i>			<i>Trailing End (Frog)</i>		
Turnout Number	Desirable Minimum	Absolute Minimum	Desirable Minimum	Absolute Minimum	
				Horizontal	Vertical
6	97'	32'	103'	38'	50'
8	108'	43'	113'	48'	64'
10	110'	44'	122'	59'	80'
15	119'	55'	146'	88'	120'
20	141'	74'	169'	116'	160'

Tangent distances between turnout point of intersection and the beginning of horizontal or vertical curve were developed based on the following criteria:

- Desirable distances are obtained by locating the beginning of horizontal or vertical curves at a point that is 75 feet from point of switch or point of frog.
- Absolute minimum distances are obtained by locating the beginning of horizontal or vertical curves 10 feet ahead of the point of switch. Non-superelevated horizontal curves begin beyond the furthest end of the joint bars connecting the running rail to the heel of frog. Vertical curves and superelevated horizontal curves shall not begin until the last long tie of the turnout set on the frog end.

Turnouts are set to provide connections to branch lines, end double tracks, yards, and industry tracks. Crossovers consist of two turnouts located to allow traffic to cross over from one track to another, usually parallel track. Where a pair of crossovers is required it should be set as two single crossovers if at all possible. If this is not possible, a double crossover may be used with the approval of UTA.

The size or “number” of the turnout or crossover selected depends upon its purpose, train speeds, and geometric constraints. The normal and maximum operating speeds through the various turnouts designated for use on the project are shown in Table 4-3.

Table 4-3: Turnout Operating Speeds (mph)

<i>Turnout Number</i>	<i>Maximum (3" U)</i>	<i>LRV</i>	<i>Freight</i>
6	14	10	Not used
8	19	15	10
10	24	20	15
15	37	30	25
20	50	45	35

For design purposes, the normal operating speed shall be used. The usual assignment of turnouts is given in Table 4-4.

Table 4-4: Application of Turnouts

<i>Turnout</i>		<i>Service</i>
<i>Frog</i>	<i>Switch</i>	
6	13'-0"	Minimum for LRT yard tracks
10	19'-6"	Minimum mainline track turnout Permanent turnbacks preferred where possible in yard
20	39'-0"	Ends of double track or mainline junctions Preferred turnout

Special turnout designs—such as curved frog turnouts and equilateral turnouts—may be advantageous at specific locations. In any such case, the justification for the design shall be rigorously documented and the special design shall not be used without the approval of the UTA Light Rail Project Director.

The separation distances required between points of intersection of various combinations and directions of turnouts are shown in Tables 4-5 to 4-7. These values are subject to change depending upon determination of final LRV characteristics.

Table 4-5: Point-to-Point Turnouts, Either Hand

<i>Turnouts</i>	<i>Desirable</i>	<i>Point-to-Point Distance (feet)</i>
-----------------	------------------	---------------------------------------

		<i>LRT only (min.)</i>	<i>LRT and Freight (min.)</i>
# 6 into:			
# 6	102.50	77.50	87.50
# 8w	101.67	76.67	86.67
13'-0" sw	112.25	87.25	97.25
# 8w	112.67	87.67	97.67
19'-0" sw			
# 10			
# 10 into:			
# 10	122.83	97.83	107.83
# 15	133.58	108.58	118.58
# 20	152.46	127.46	137.46
# 20 into:			
# 20	182.08	157.08	167.08

Table 4-6: Frog-to-Point Turnouts, Same Hand

<i>Leading Turnout</i>	<i>Trailing Turnout</i>	<i>Frog-to-Point Distance [feet]</i>		
		<i>Desirable (14'-0" Center or Clear Tie Sets)</i>	<i>12'-6" Center or Clear Tie Sets</i>	<i>Minimum*</i>
# 6	# 6	84.5839	75.5213**	77.4167
	# 8w 13'-0" sw	**	**	76.5833
	# 8w 19'-6" sw	**	**	87.1667
	# 10	**	**	87.5833
# 10	# 10	140.3522	125.3144	109.2500
	# 15	122.5000	122.5000	120.0000
	# 20	141.3750	141.3750	138.8750
# 20	# 20	280.1775	250.1585	203.3750

* Based on 19' rail (13'-0" with # 6 and # 8w 13'-0" switch) between frog and stock rail.

Will require curve beyond heel of switch in lead turnout to provide clearance.

** Do not use, because value is less than minimum.

Table 4-7: Frog-to-Point Turnouts, Opposite Hand

Leading Turnout	Trailing Turnout	Frog-to-Point Distance (feet)	
		Desirable (Clear Tie Set)	Minimum*
# 6	# 6	**	77.4167
	# 8w 13'-0" sw	**	76.5833
	# 8w 19'-6" sw	**	87.1667
	# 10	**	87.5833
# 10	# 6	101.5833	100.3333
	# 8w 13'-0" sw	100.7500	99.5000
	# 8w 19'-6" sw	111.3333**	116.0833
	# 10	111.7500**	116.5000
	# 15	122.5000**	127.2500
	# 20	141.3750**	146.1250
# 20	# 8w 19'-6" sw	206.3333	173.3333
	# 10	206.7500	173.7500
	# 15	217.5000	184.5000
	# 20	236.3750	203.3750

* Based on 19' rail (13'-0" with # 6 and # 8w 13'-0" switch) between frog and stock rail.

Will require curve beyond heel of switch in lead turnout to provide clearance.

** Do not use, because value is less than minimum.

Special track work shall be located so as to minimize or eliminate the exposure of pedestrians to the operating mechanisms and to open flangeways. Pedestrian crosswalks shall not be located across switches, frogs, and crossing diamonds. Switches shall not be located in areas of vehicular traffic so as to avoid any need for special tongue switch designs and to enhance the safety of UTA employees engaged in switch maintenance.

Special track work geometry and details should avoid or minimize any requirements for special catenary and signal structures.

As all special track work is a source of noise and ground-borne vibration, its proposed location shall be determined with due consideration given to those factors.

Special track work shall be designed for welded joint installation except at insulated joint locations. Where bolted joints in special track work are unavoidable, the joints shall be configured to permit epoxy bonding of "D-bar" type joint bars. Turnouts to industrial sidings shall be partially welded installation eliminating bolted joints along the mainline traffic rails.

Running surfaces in special track work shall either have or be treated to provide a minimum hardness of Brinell 320.

Provisions shall be made during the design of special track work for the installation of switch heaters of the "Calrod" tube type. All switches shall be designed to accommodate switch heaters regardless of the location of the specific installation within the system or the need for switch heaters at that location. All power-operated switches shall be equipped with switch heaters at the time of initial construction and provisions shall be made for switch heater installation on all manual switches.

Whenever possible switches in paved track shall be of the common AREMA split switch design. Such switches shall be enclosed in a suitable robustly-constructed housing that permits the operation of rubber tired vehicles anywhere in the switch area. Tongue switches shall not be used unless approved by the UTA Project Director.

4.24 Switch Machines—Power Operated and Manual

Switches may be operated by power operated switch and lock movements, electrically locked hand-operated machines, or hand-operated trailable switch stands, depending on the location and purpose of the switch. Selection of a switch operating device and the space requirements for such devices shall be coordinated with design of the signal system and Chapter 13.

4.25 Rail Expansion Joints

Where thermal forces in the rail cannot be restrained and rail expansion and contraction must be accommodated, rail expansion joints shall be provided. An example is any existing structures that must be protected from longitudinal rail force transfer. Another example is a bridge expansion dam where the rails are embedded in the surface of a paved roadway bridge. Where the amount of rail movement that needs to be accommodated is 2 inches or less, or if the joint is located in a paved bridge deck, a mitered design expansion joint may be used. If rail expansion in excess of 2 inches must be provided, open track rail expansion joints of the sliding rail type shall be provided.

Where rail expansion joints are provided in paved track, provisions shall be provided for the inspection and maintenance of the joints. The joint housing shall include drainage provisions so that storm water and detritus that enters the joint can be flushed away.

4.26 At-Grade Crossings

At-grade street crossings should be modular grade crossing panels placed on asphalt pavement or other manufacturer recommended base course. The design of at-grade crossings of yard and secondary track shall be based upon the use of asphalt, concrete, rubber, or bolted timber panels.

4.27 Miscellaneous Track Appurtenances

4.27.1 Buffer Stops

Buffer stops shall be used at all stub ends of track to stop an LRV in the event of mechanical failure of the braking system or human error. The buffer stops shall be designed to engage the vehicle anticlimber without contact with the vehicle coupler and to limit vehicle body damage for the anticipated operating speed.

The buffer stop design shall be based on the energy absorption capacity of the friction elements required to stop an LRV based on the following parameters:

- Kinetic energy of a 4-car LRV consist (AW3 loading) at 10 mph
- Slide area gradient < 1.5%
- Maximum deceleration rate < 1.0 g
- Force limit imposed by shock absorbers < vehicle buff load

The buffer stop design shall define the following elements:

- Main frame and slave frame steel strength
- Buffer shoes and hardware
- Frame hardware
- Shock absorber head and attachment hardware
- Welding procedure
- Paint thickness and durability
- Field installation and repair procedures

4.27.2 Embedded Track Drains

The flangeways provided for the light rail vehicle wheels in embedded track form natural conduits for storm water runoff. In order to prevent the formation of ponds and icing at low points of sag vertical curves, track drains shall be used. Such drains shall also be placed at appropriate intervals along grades to prevent the flangeways from overflowing. A track drain shall be placed on the downgrade end of all embedded track which adjoins ballasted track or direct fixation track so as to minimize fouling of the track ballast with street detritus. Similarly, a track drain shall be provided at the downgrade end of any paved track segment that abuts a segment of direct fixation track so as to prevent street detritus from creating a housekeeping problem in the direct fixation track area. Other locations where the use of track drains may be appropriate shall be identified during final design.

4.27.3 Rail Lubricators

Automatic train-sensing rail lubricators shall be considered and evaluated for any track work with horizontal curve of 500' radius or less. In some cases, rail lubricators have reduced significant noise caused by rail transit. Each curve will be evaluated on a case-by-case basis and the decision must be approved by the Project Director.

END OF CHAPTER 4.



Utah Transit Authority Light Rail Design Criteria

Chapter 5 Civil Work

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 5 CIVIL WORK

5.1 General

This section establishes the basic civil engineering criteria to be used in design of light rail transit facilities.

Civil design in public rights-of-way shall be in conformance with the specification and design guidelines of UDOT Standard Drawings or as determined otherwise for the local agency having jurisdiction.

Drainage shall meet the requirements and design guidelines of the local agency having jurisdiction for the subject drainage.

5.2 Grading

The maximum slopes for cut slopes and fill slopes shall be as follows:

- 4:1 for 10' elevation differentials
- 2:1 for over 10' high elevation differentials in cuts
- 3:1 for over 10' high elevation differentials in fills
- Cut slopes in rock may vary according to geotechnical recommendations

In areas where fill slopes may encroach upon properties adjacent to the UTA right-of-way, the use of retaining structures shall be considered.

Embankment widenings coincidental with drainage structures will consider the use of retained embankment in lieu of structure extensions. Solutions for final design will be based on cost effectiveness as well as constructability and maintainability.

Standards noted are consistent with UDOT Standard Drawings. Slopes are also subject to variation upon recommendation where existing right-of-way is restrictive and costs for providing additional right-of-way would be excessive. Grading designs shall incorporate the erosion control requirements in the UDOT Standard Drawings.

5.3 Roads and Paving

5.3.1 General

For general project consistency, the design standards for arterial, collector, and local roads shall be in conformance with UDOT and AASHTO Standards, except as modified herein. Pavement structural cross-sections shall be designed for the anticipated traffic requirements 20 years after construction. Road reconstructions should match existing surface type.

Roads and parking surfaces shall be either Portland cement concrete or bituminous concrete, except that bus-specific areas shall be Portland cement concrete.

5.3.2 Applicable Standards

The most current editions of these documents are incorporated into these design criteria by reference and shall be adhered to wherever possible in the design of roads, parking and related traffic control except when specified in this manual. If criteria sources conflict, the most conservative standards shall be used.

5.3.2.1 American Association of State Highway and Transportation Officials (AASHTO)

- A Policy on Geometric Design of Highways and Streets
- Roadside Design Guide

5.3.2.2 Utah Department of Transportation (UDOT)

- State of Utah Standard Specifications for Road and Bridge Construction
- UDOT Supplemental Specifications
- Standard Specifications for Highway Bridges (AASHTO)
- UDOT Manuals of Instruction
- UDOT Standard Drawings

5.3.2.3 County and Local Jurisdictions

- Applicable Ordinances and Standard Drawings

5.3.2.4 American Public Works Association (APWA)

- Applicable standards

5.3.3 Roadway Geometries

New facilities shall be designed in accordance with the criteria listed in this manual.

5.3.3.1 Traffic Lane Widths

Traffic lane widths shall conform to local jurisdictional standards.

5.3.3.2 Number of Traffic Lanes

Unless required to mitigate traffic impacts of the LRT system, as defined in the FEIS, existing roadways shall be replaced to the same dimensions. Access roads to the station facilities, as required, shall be built to accommodate anticipated traffic volumes.

5.3.3.3 Parking Lanes

Parking locations shall be determined in consultation with the jurisdictions based on traffic analysis, safety considerations, and demand for on-street parking. Twenty-four hour parking prohibition shall be recommended at those locations (i.e., near intersections and at LRT stations) where roadway width is not adequate to provide the necessary number of through lanes. Peak hour parking may be recommended at those locations where traffic analysis shows that the capacity of the traveled way provides level of service C or better.

5.3.3.4 Cross Slopes

Cross slopes shall be in accordance with local jurisdictional standards. Cross slope shall be considered when designing bus-specific paved areas.

5.3.4 Ramps and Curb Cuts

Ramps and curb cuts shall be designed in accordance with ADA requirements.

5.3.5 Sidewalks and Park Strips

Sidewalks, park strips, and planting areas, if required, shall comply with the standards of UDOT or the local agency having jurisdiction. At a minimum, all sidewalks must have at least 4 feet in clear width when adjacent to a park strip and 6 feet when adjacent to the back of a roadway curb or gutter.

For sidewalks that cross train tracks, see Section 13.5.4.

5.3.6 Driveways

Driveways shall be replaced to the minimum widths required by UDOT or the local agency having jurisdiction.

5.3.7 Bus-Related Road Improvements, Turning Radii, and Bus Stop Placement Criteria

Standards for bus-related road improvement designs, dimensions, and arrangements shall conform to Figures 5-1 through 5-6.

5.3.7.1 Bus Shelter Pads

Bus shelter pads must be located, sized, and oriented in accordance with ADA regulations and coordinated with bus shelter type and bus operations.

5.3.8 Bus Loading Zones

Bus loading zone designs in order of preference are sawtooth, recessed, and parallel to curb. Dimensions and arrangements shall conform to Figures 5-7 through 5-11, respectively, as appropriate.

Figure 5-1: Standard Design Vehicle Bus

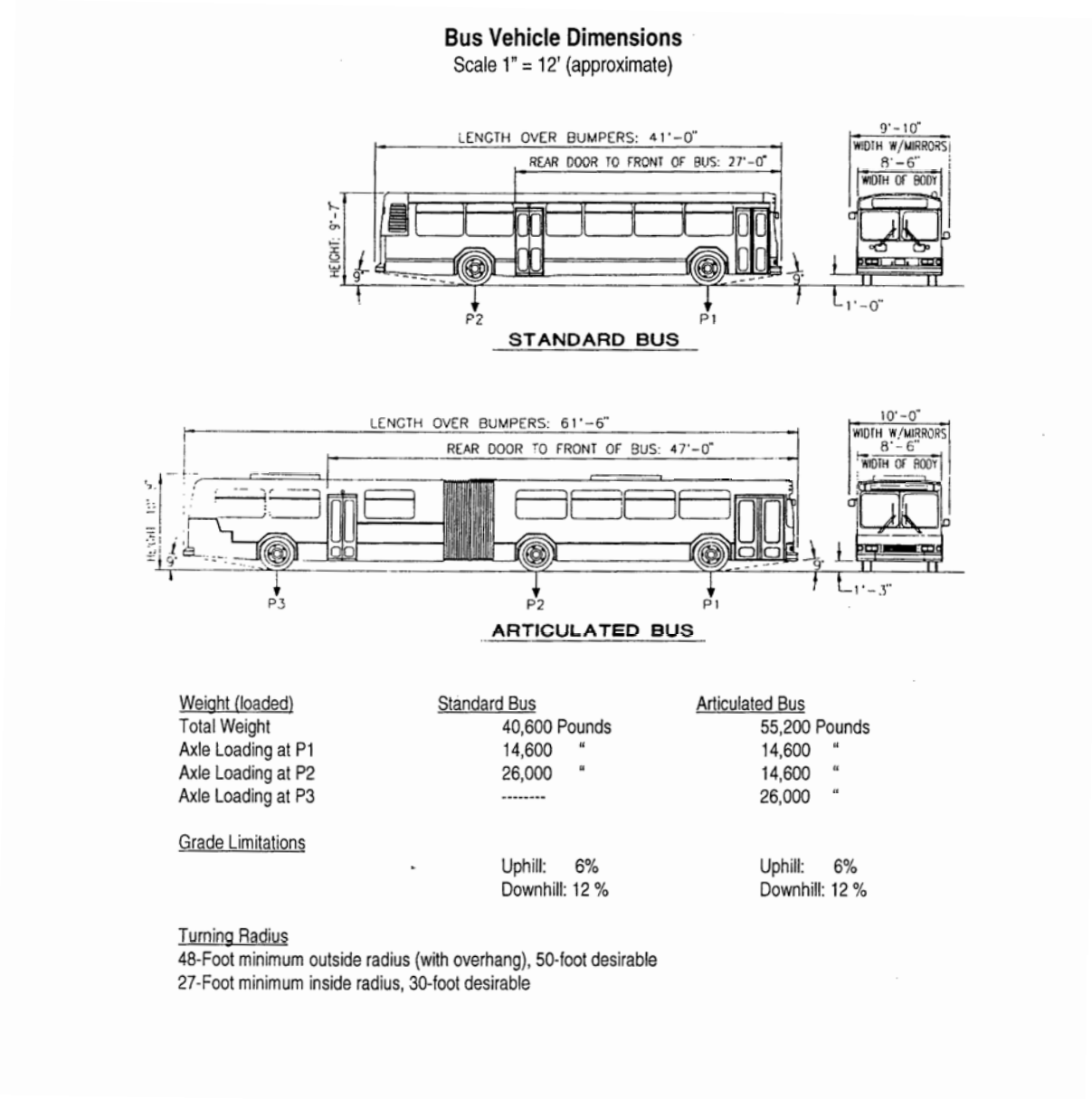
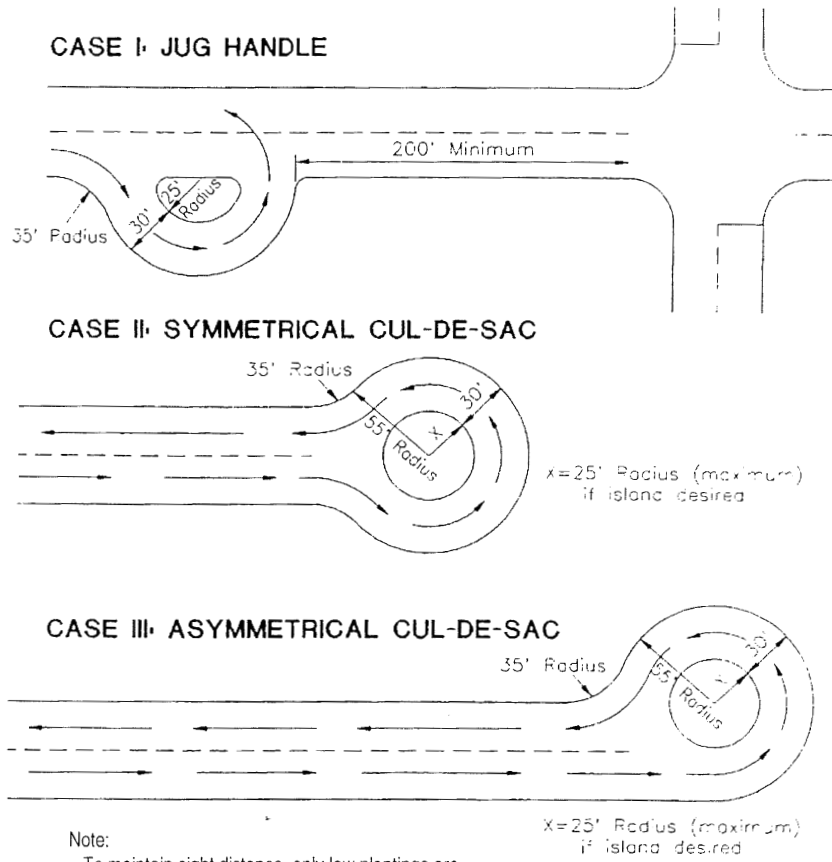


Figure 5-2: Bus Turn Arouds

Bus Turnarounds

Scale: 1" = 60'



Note:
To maintain sight distance, only low plantings are recommended in island areas.

30' lane width assumes no parking in loop area.

Figure 5-3: Intersection Design for Bus Turns

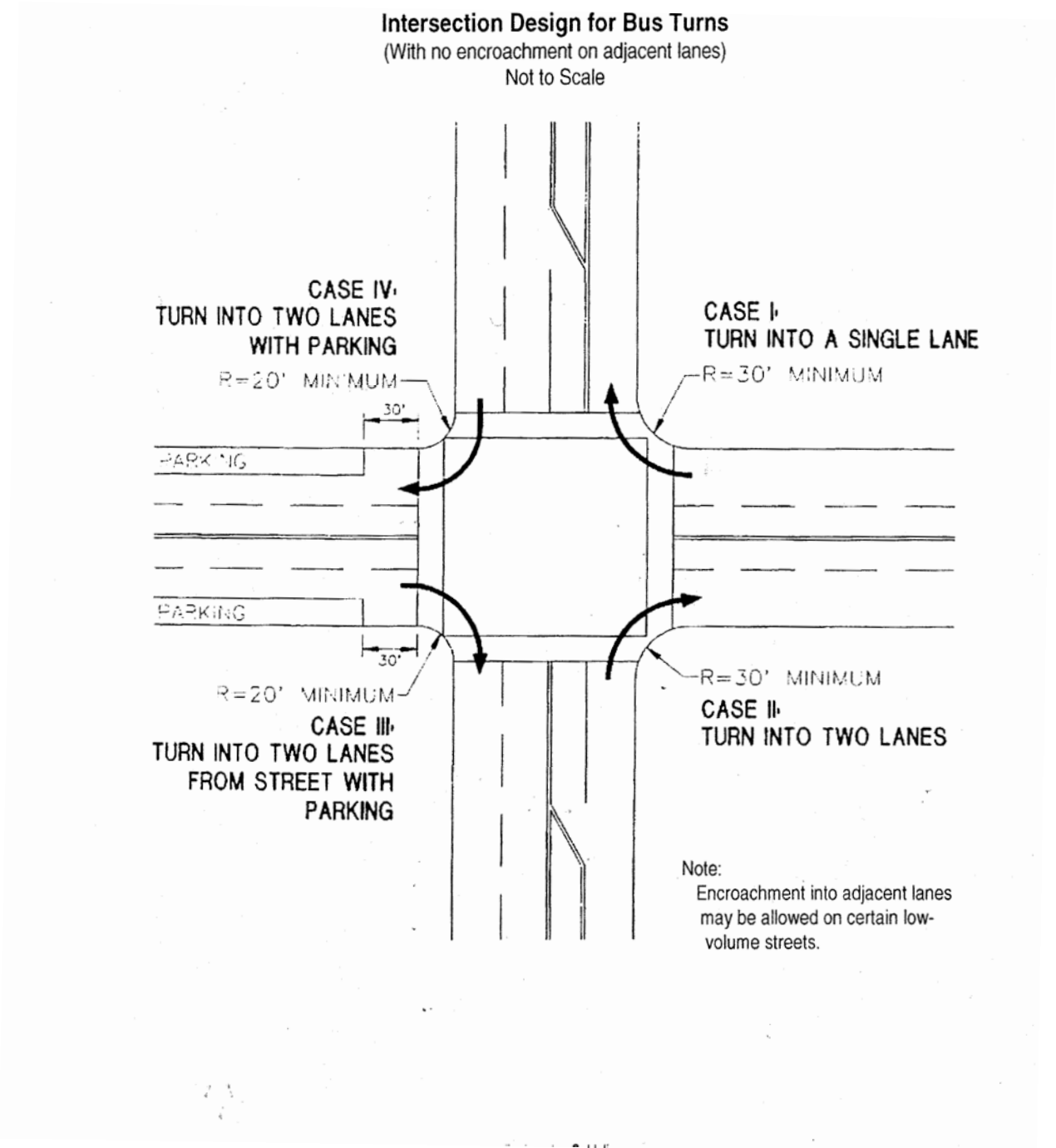


Figure 5-4: Bus Turning Template

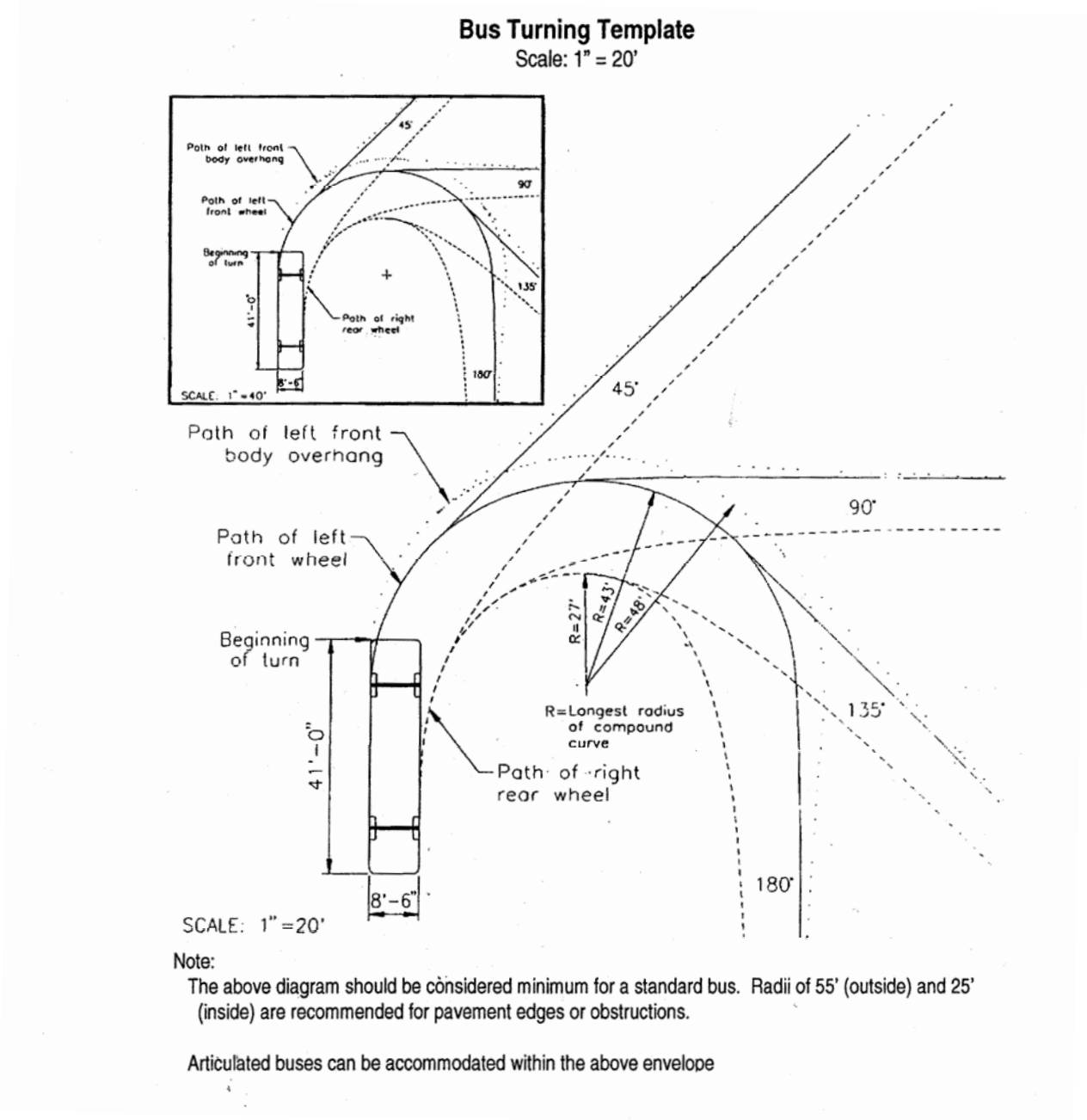
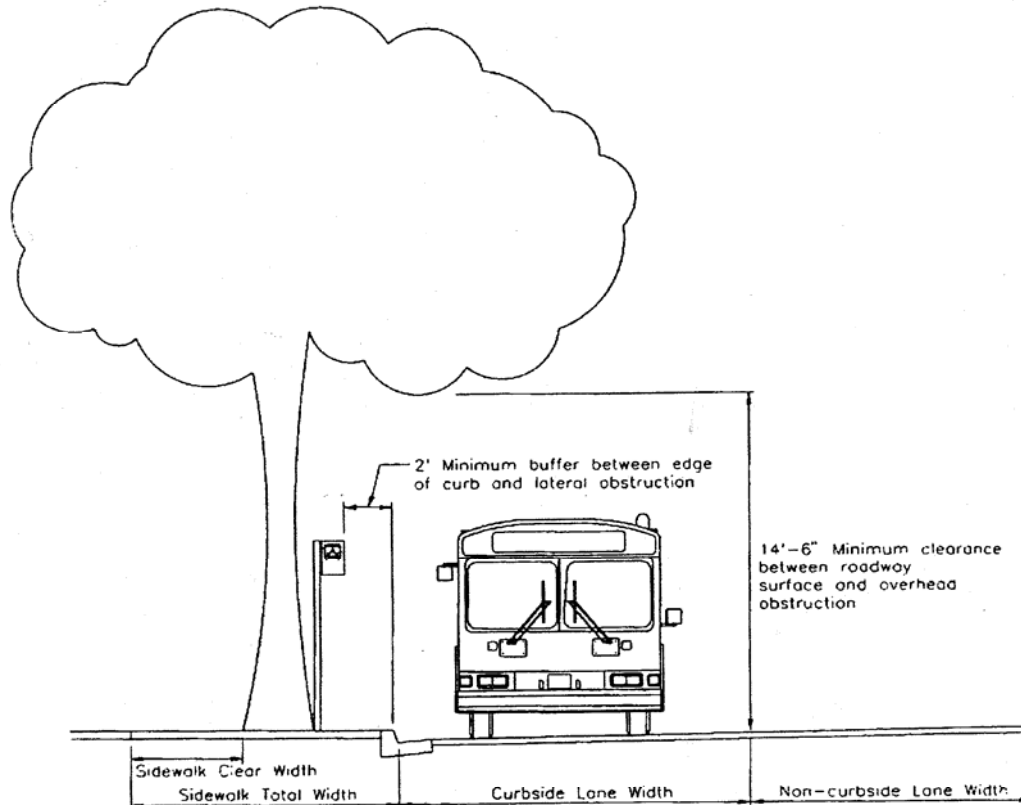


Figure 5-5: Vertical and Horizontal Clearances for Buses

Vertical and Horizontal Clearances for Buses

Scale: 1" = 6' (approximate)



	Sidewalk Clear Width		Curbside Lane Width	Non-curbside Lane Width
	Sidewalk Total Width			
Total Width At Bus Stops:	10' Minimum 15' Desirable in Commercial Areas	No Parking:	12' Minimum 14' Desirable	11' Minimum 12' Desirable
Between Bus Stops:	5' Minimum 8' Desirable	With Parking:	18' Minimum 20' Desirable	

*Lane widths narrower than 11' will result in encroachment into adjacent lanes.

Note:

Sidewalk clear width should be 4' minimum, 6' desirable; where pedestrian traffic is heavy, up to 8' clear width should be reserved

Figure 5-6: Pavement Composition

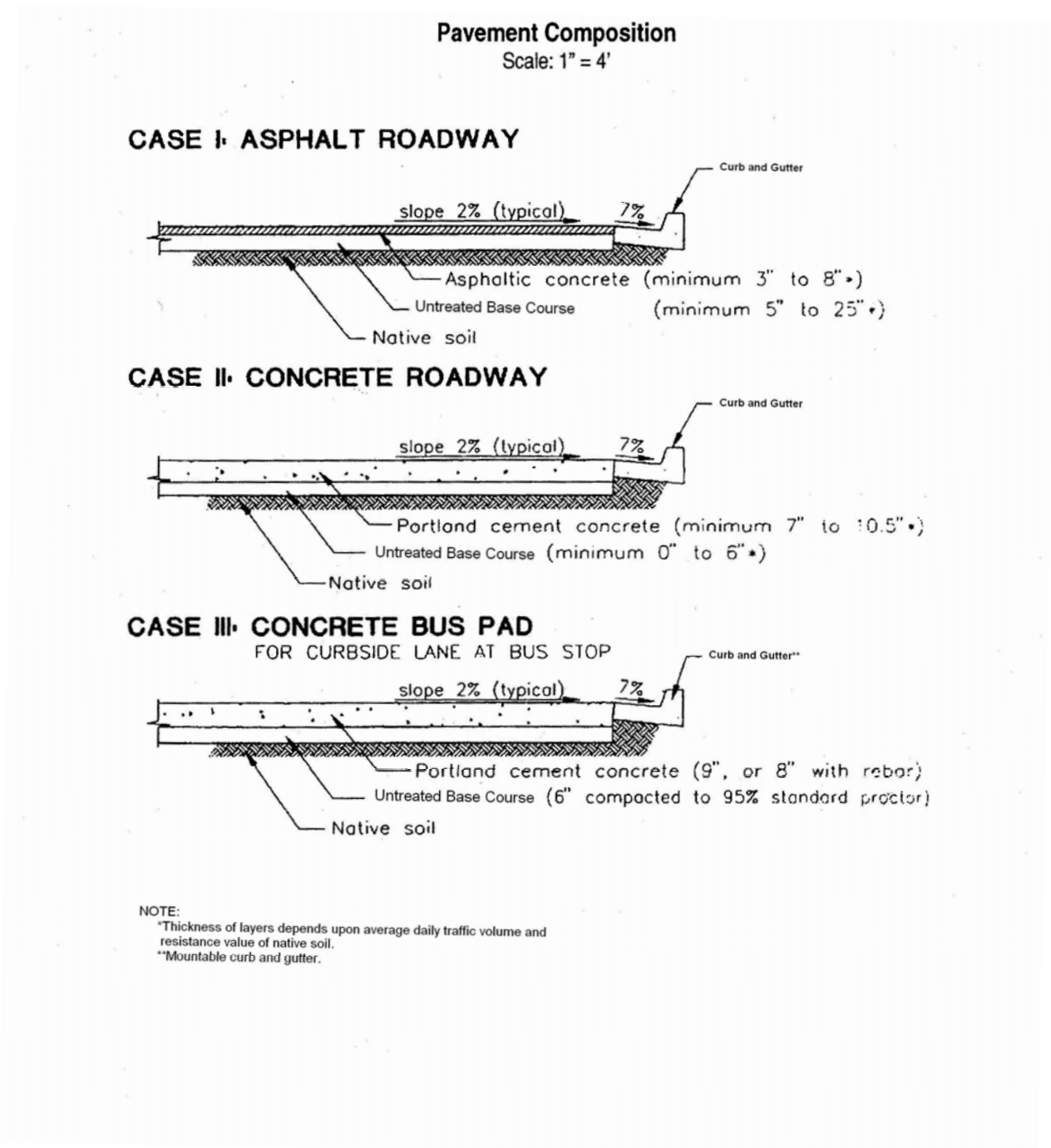


Figure 5-7: Park-and-Ride Layout

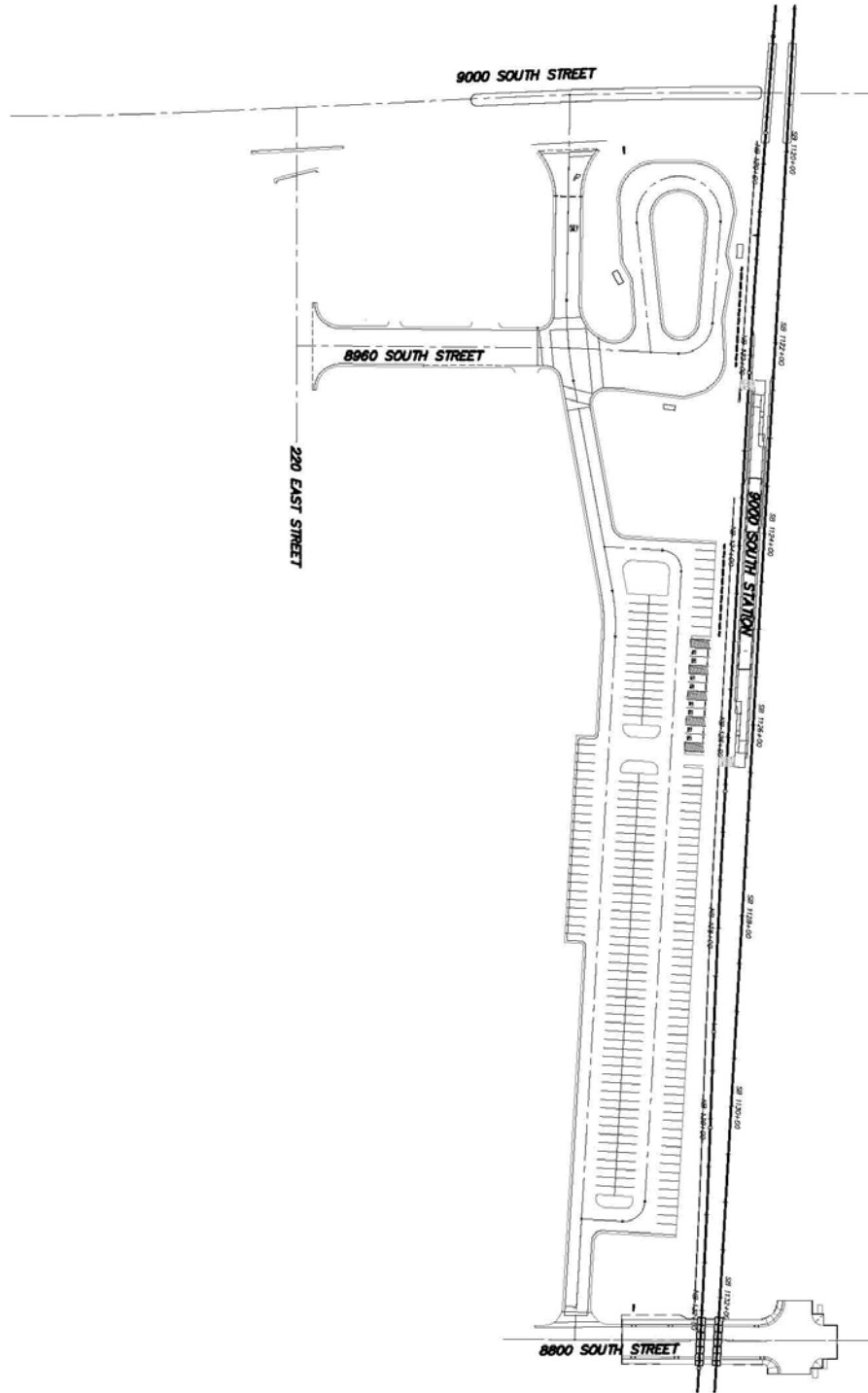
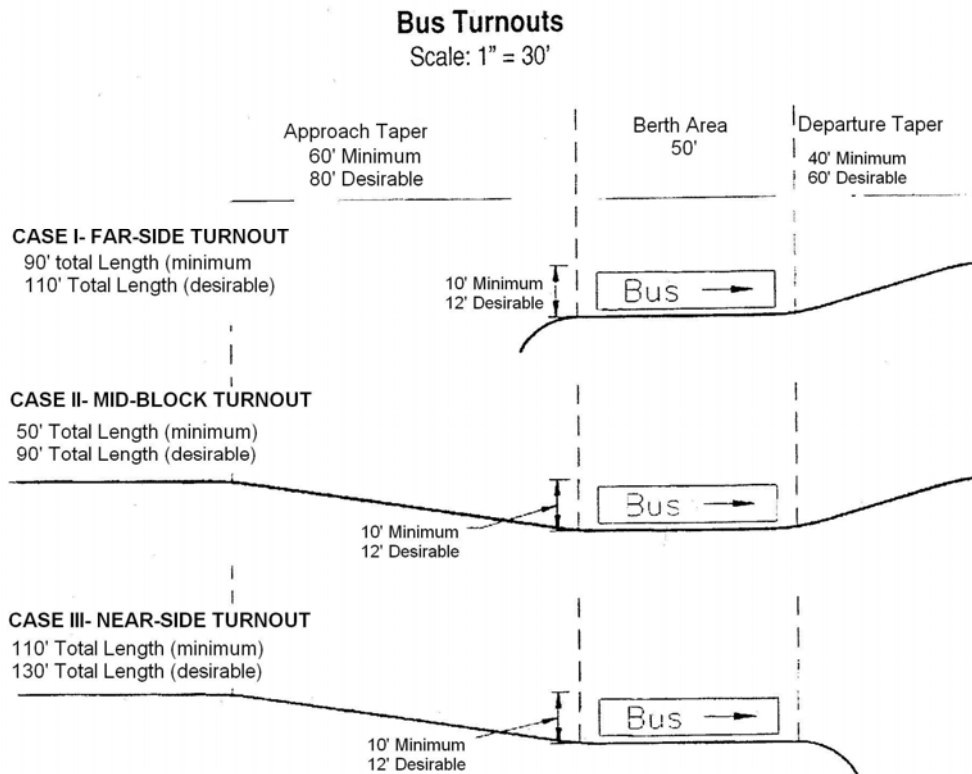


Figure 5-8: Bus Turnouts



Berth Area Note:

Add 20' to length of berth area if articulated buses will use turnout; add 70' more for each additional articulated bus expected to use the turnout at the same time.

Add 50' for each additional standard bus expected to use the turnout at the same time.

Departure Area Note:

Dimensions of taper assume that buses will accelerate mostly in the departing travel lane.

Note:

Bus turnouts are widened sections of roadway designed for buses to pull out of the traffic stream. While advantageous to general traffic, turnouts make it difficult for buses to re-enter the flow of traffic.

Figure 5-9: Bus Passenger Shelter Placement

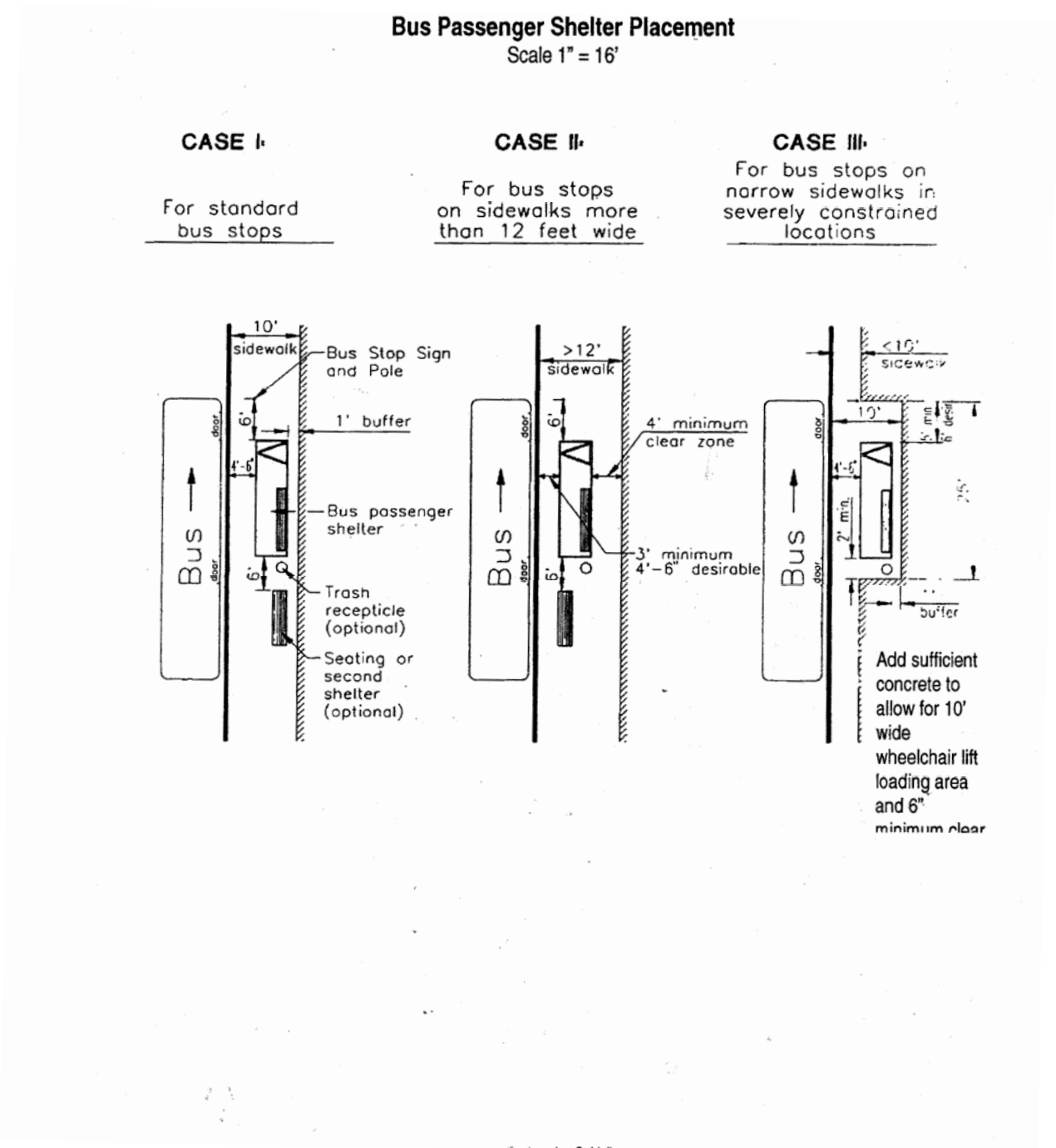


Figure 5-10: Off-Street Bus Stations

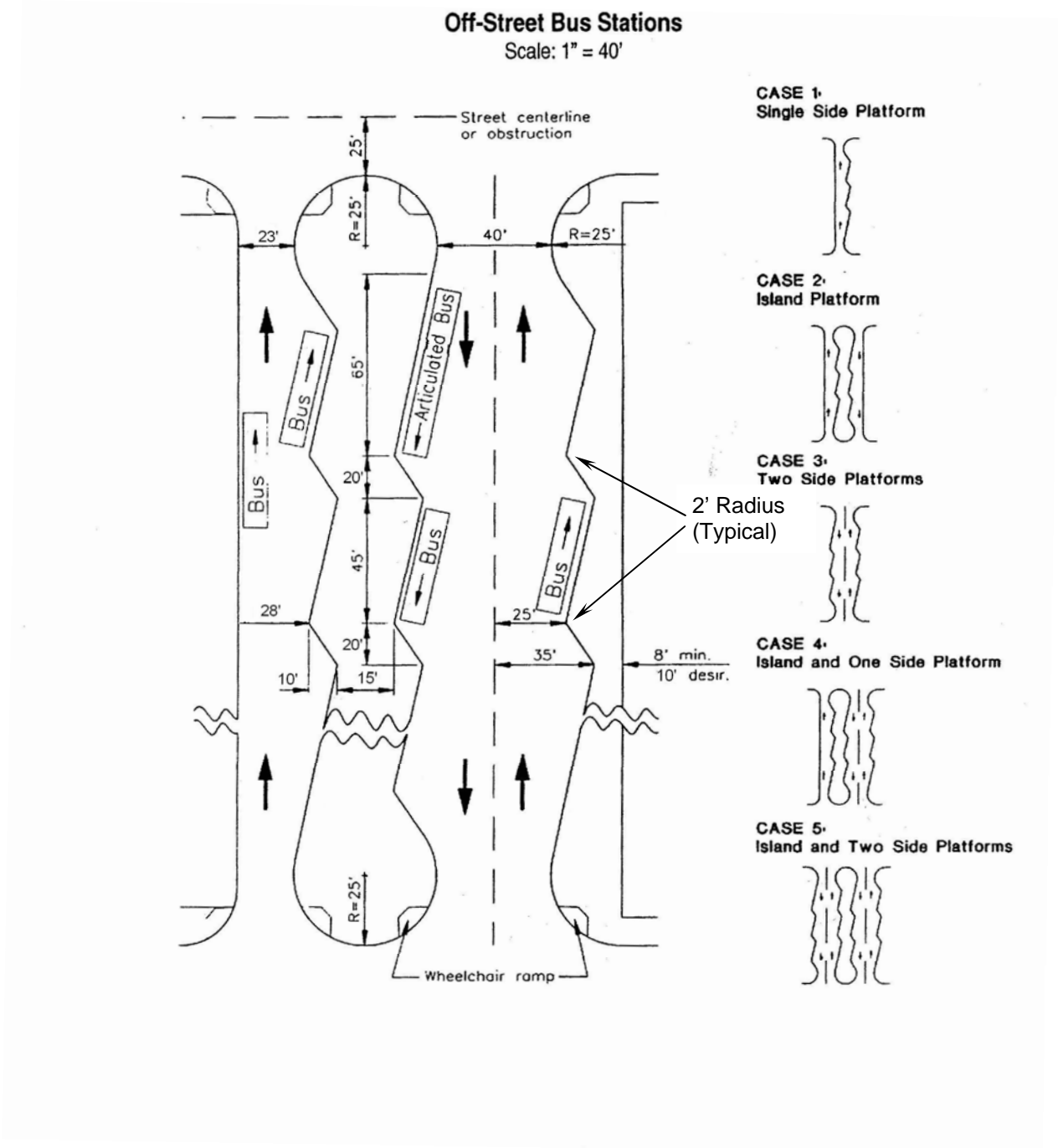
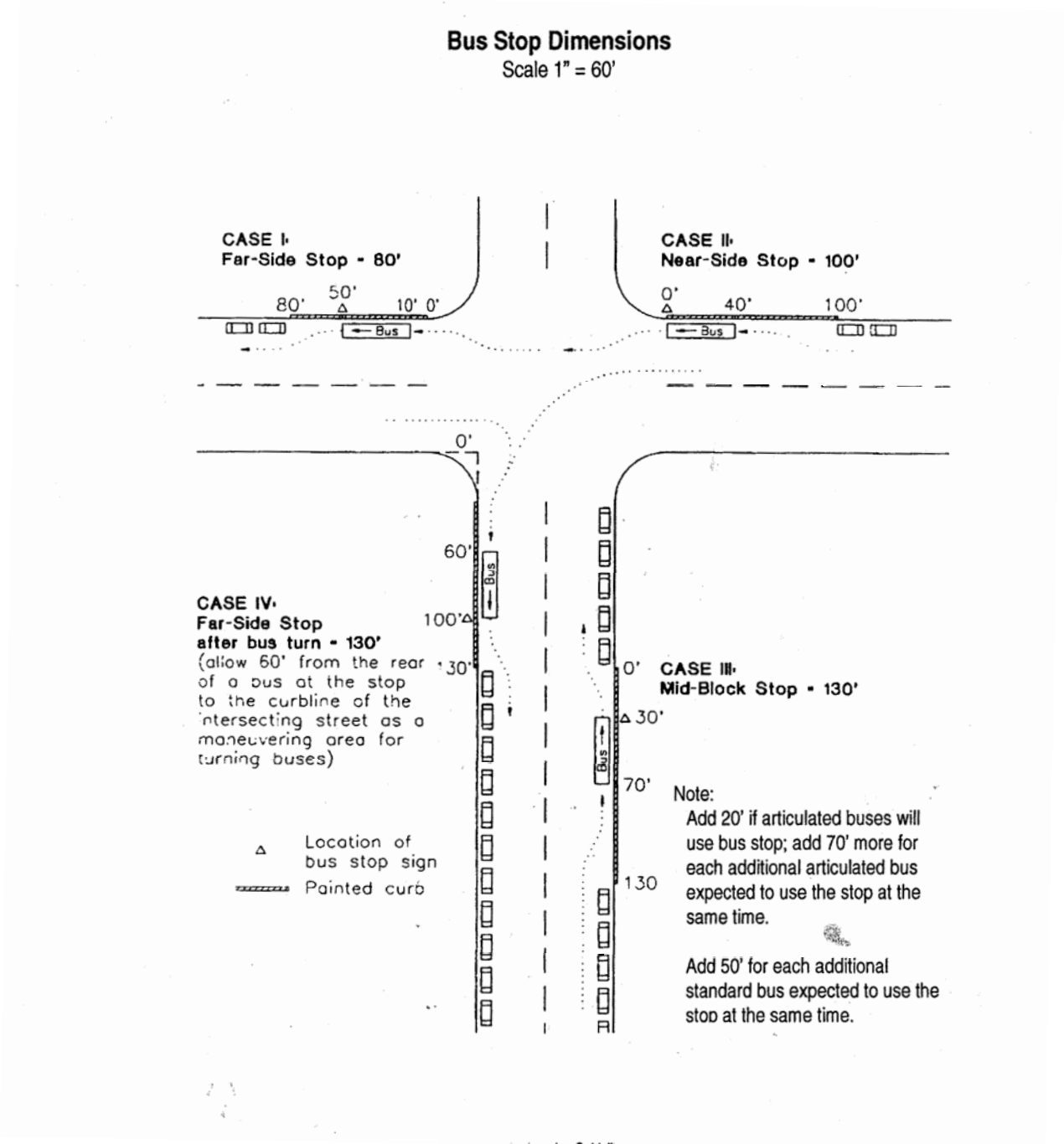


Figure 5-11: Bus Stop Dimensions



5.3.9 Paving

Restored asphalt or concrete roadway pavements shall be of similar materials existing prior to transit construction. Pavement thickness shall be determined by the geotechnical consultant after the existing pavement conditions are determined through testing. The pavement design shall be prepared according to AASHTO criteria.

For paving restoration for utility and drainage trenches, the asphalt and concrete pavement shall be replaced according to the standard specifications and practices of the jurisdiction having authority.

Bus loading zones or stops shall be Portland cement concrete.

5.3.10 Traffic Maintenance

The design drawings for traffic maintenance during construction shall be in accordance with the latest edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) and shall include the traffic staging and detour plans approved by UDOT and/or local agencies.

5.4 Drainage

5.4.1 General

The design of drainage systems using the criteria contained herein is to protect the light rail system and adjacent facilities from storm runoff damage, and to provide for environmentally responsible handling of storm drainage during construction.

The design of new drainage facilities shall be in accordance with the criteria of Salt Lake County and, as applicable, the local agency having jurisdiction.

Required relocation of existing drainage facilities shall be “replacement-in-kind” or “equal construction,” where the light rail transit construction does not change the design flows. Local agencies having jurisdiction over drainage shall be consulted regarding up-sizing of existing facilities to be replaced.

5.4.2 Submittals

Design of drainage facilities requiring review and approval of jurisdictional agencies shall be submitted in accordance with the procedures established by the respective agency. All maintenance during construction, relocation, and restoration of drainage facilities shall conform to the most current edition of the respective design criteria, as listed below, for the agencies that may be affected by LRT drainage construction.

- Utah Department of Transportation: UDOT Standard Drawings and Specifications and the UDOT Manuals of Instruction
- Salt Lake County criteria
- Applicable local jurisdiction

5.4.3 LRT Drainage

LRT drainage criteria apply to the design of drainage facilities in the LRT right-of-way which shall be maintained by UTA.

Invert elevations and the location of drainage facilities at the ends of contract design segments shall be coordinated to include provisions for future LRT construction.

Drainage shall be by gravity flow. Where sections are below points where gravity outfalls cannot be provided, pumping stations may be necessary, subject to the approval of the UTA Light Rail Project Director.

No sanitary sewer discharge shall be permitted to enter any drainage system.

5.4.4 Hydrology and Hydraulics

The following procedures shall be used in preparing hydrologic computations for LRT drainage.

5.4.4.1 Design Method

- All storm water facilities draining 5 acres or less shall be designed for the maximum expected discharge, determined by the Rational Method.
- All storm water facilities draining more than 5 acres shall be designed for the maximum expected discharge, determined by using the soil conservation service methodology presented in “Technical Release 55 (TR-55), Urban Hydrology for Small Watersheds.”

5.4.4.2 Storm Frequency

The following facilities shall be designed/protected by accommodating the storm frequency listed:

- | | |
|---|------------------------------------|
| • All culverts and drainage facilities crossing the LRT system where flooding could damage the system | 50-year design
(100-year check) |
| • Track roadbed (to top of subballast) | 50-year |
| • Main storm drains | 50-year |
| • Parking lots, roadways, street-running track | 10-year |
| • All longitudinal drains or subdrains that could flood roadbed | 50-year |

Storm facility design shall be in accordance with local jurisdictional requirements.

5.4.5 Selection of Drainage Structures

Drainage structures shall generally be selected from Salt Lake County, UDOT, or local jurisdictional standards. When conditions occur for which the standard drainage structures are not suitable, the engineer shall modify these structures or design special structures which satisfy the conditions.

5.4.6 Pipe Materials

- Storm drains shall be minimum of 18" diameter.
- Underdrains shall be minimum of 8" diameter.
- Crossing culverts shall be a minimum of 24" diameter.
- Pipe materials shall be chosen based on a life cycle analysis, and shall conform to local jurisdictional requirements.

Cathodic protection for these pipes may be required. Refer to Chapter 16.

5.4.7 Location of Drains

In the track sections, manholes or cleanout boxes shall be provided at maximum 400 foot spacing for the selected type. Inlets shall be provided at required drainage catch points.

Underdrain cleanouts shall be provided at maximum 100 foot centers (50' desirable) along all drainage lines. A cleanout is required for each bend. Clean out boxes shall not be located between light rail tracks.

5.4.8 Parking Lots

Parking lots shall be designed so that storm water is removed by overland flow to a gutter or curb and gutter then to an inlet where the water shall enter either a closed drainage system or an open ditch. The maximum velocity of flow out of the parking lot shall be as directed by local criteria. Overland flow should be on at least a 1% grade. The maximum permissible spread for gutter flow shall be 12 feet.

5.4.9 Storm Water Management and Sediment Control

Where construction activities will disturb 5 or more acres of land, the design shall comply with the Utah Pollutant Discharge Elimination System (UPDES) Permit Requirements, as regulated by the State of Utah, Department of Environmental Quality, and Division of Water Quality (DWQ). At a minimum, erosion and sediment control plans shall be in accordance with Chapter 70 of the International Building Code¹ (IBC), and the Wastewater Disposal Regulations Part II, Standards of Quality for Waters of the State (distributed by the DWQ).

5.4.10 Detention Requirements

The use of detention facilities will be required in areas where the proposed runoff volume is 5 cfs or greater than the existing runoff volume at a specific outfall location. The detention facility will be designed to release at the existing runoff rate or the regulatory rate depending on which is more stringent. Detention facilities at the station site will be designed for the 10-year, 24-hour event and detention facilities along the railroad corridor will be designed for the 50-year, 24-hour event.

5.5 Surveying and Mapping

5.5.1 Survey Control System

5.5.1.1 Horizontal Control

- All horizontal controls shall be based on the Utah State Plane Coordinate System, Northern Zone.
- The accuracy of the primary horizontal ground control surveys shall be, as a minimum, ACSM Second Order Class II Survey, 1:25,000. Spacing of primary horizontal ground control survey points shall be at approximately every mile.
- The accuracy of the secondary horizontal ground control surveys shall be, as a minimum, ACSM Second Order Class II Survey, 1:10,000. Spacing of secondary horizontal ground control survey points shall be at approximately 2 mile intervals.

¹*International Building Code*. Country Club Hills, IL: International Code Council, Inc., current edition.

- Subsequent horizontal surveys shall, as a minimum, have an accuracy of ACSM Second Order Class II, 1:10,000.
- Aerial control points shall be established at approximately 900-foot intervals utilizing the primary and secondary horizontal ground control and intermediate points as applicable. Wing points shall be located 600 feet each side of the aerial control points and shall be established at an accuracy of 0.1' horizontal.

5.5.1.2 Vertical Control

- Vertical controls for this project shall be based on the National Geometric Survey (formerly USGS) mean sea level datum established in Salt Lake County.
- The vertical accuracy, in feet, of the primary and secondary horizontal ground control network shall be at an accuracy of 0.035 feet times the square root of the distance run in miles (i.e., for a one-mile level loop survey the vertical accuracy is equal to $0.035 \sqrt{1} = 0.035$ feet).
- The accuracy of the intermediate aerial control points shall be the same as for the primary and secondary ground control network. The vertical accuracy of the aerial wing points shall be 0.1 feet.

5.5.2 Surveys and Monumentation

All existing monuments are to be shown on the plans, and restored to their original locations if disturbed during construction.

Temporary monuments shall be used during the preliminary engineering phase. During final design, when all of the right-of-way requirements are finalized, permanent monuments shall be placed at each PC and PT of right-of-way line curves, and as necessary to satisfy involved jurisdictions.

5.6 Right-of-Way

5.6.1 General

Right-of-way is the composite total requirement of all interests and uses of real property needed to construct, maintain, protect, and operate the light rail transit system. Some right-of-way requirements are temporary and reversionary in nature, while other requirements are permanent as dictated by operating needs. The intent is to acquire and maintain the minimum right-of-way required consistent with the requirements of the system and good right-of-way practices. Because right-of-way plans approved by UTA are used as a basis for acquisition of property, all interests and uses required shall be shown on the right-of-way plans together with the detailed property dispositions.

The limits of permanent right-of-way shall be shown on the right-of-way plans as an unbroken line utilizing simple curves and tangents described by bearings and distances. Spiral curves shall not be used in right-of-way descriptions. Chords may be used in lieu of curves under special conditions approved by UTA.

Right-of-way requirements for aerial or underground transit facilities are described herein, should a future need for them arise.

5.6.2 Definition of Types of Rights-of-Way

5.6.2.1 Fee Simple Title

- Fee simple title is full ownership of property.
- Fee simple title should always be the first type of right-of-way to be considered for any surface or aerial construction. If this is not practical, then another type of right-of-way should be used.

5.6.2.2 Easements

Permanent Surface Easement with an Upper Limit

A non-possessing interest held by one party in land of another whereby the first party is accorded permanent but partial use of such land for a specific purpose.

- An easement that provides space for the transit structures and for the future maintenance of structures that support aerial facilities located on private property. This easement shall have definite lateral limits that shall be described on the drawings. Where required, upper and/or lower limits shall be described.
- The recommended easement width shall include basic track width, drainage, supporting slopes, and utilities, and must consider the overall effect on the affected property.

Permanent Underground Easements

An easement that encompasses the total transit facility located beneath the surface of the ground. It shall have definite upper and lateral limits that shall be shown on the drawings. Lower limits shall be described only where special limiting features exist.

Permanent Aerial Easements

An easement that completely envelopes the aerial portion of the transit facility. Its lower and side limits shall be shown on the drawings. Where required, upper limits shall be described.

Construction Easements

An easement, temporary in nature, but with a definite duration, that provides sufficient space to allow for the use of the property by the contractor during construction.

Public Utility Easements

Required utility easements shall be treated as right-of-way. Bearings and distances along the sides shall be shown as well as the length and widths of the easements and ties to the limits of the right-of-way. All easements shall be in accordance with local and utility regulations.

5.6.3 Right-of-Way Limits

The following criteria are provided as a general guideline for establishing the limits of the right-of-way. The dimensions are given for minimum conditions and must be modified where engineering or real estate requirements dictate additional needs. All right-of-way limits shall be vertical or horizontal planes. Where right-of-way of freight railroads already exists and is determined to be generally sufficient for transit facilities and operations, then these guidelines shall be applied only as determined necessary under consideration of the UTA Light Rail Project Director.

5.6.3.1 At-Grade Construction

Upper Limit

Normally, an upper limit is not required. When an upper limit is required, the limit shall be described by the elevations of horizontal planes, stepped as required, and co-locating the steps with existing property lines or prominent suitable topographical features. The minimum desirable vertical distance from top of catenary support structure to horizontal plane above is 5.0'.

Lateral Limit

- On exclusive right-of-way, the minimum allowable distance from the centerline of the nearest track to the limit of the right-of-way is 10'-6".
- On restrictive rights-of-way, the preferred minimum right-of-way is 35.0' for two tracks.

The right-of-way needed shall depend upon the nature of the track use (joint or exclusive LRT), clearances, and whether slope banks and retaining walls or other structures are required. The minimum widths of right-of-way for the approximately level cross-section including the trackbed and the catenary system support poles are 35 feet for open areas.

Additional right-of-way may be required for the entire trackway including associated slope banks and structures depending upon the ownership and maintenance responsibilities of those facilities. All tie-back systems should fall within the obtained right-of-way. Additional rights-of-way may be required for access roads and drainage facilities.

Where tracks are to be placed in streets and automotive traffic and LRT traffic shall be mixed, the minimum widths of right-of way is 28 feet, inclusive of the catenary system.

- Additional distances required, such as for additional tracks, maintenance roads and drainage ditches, shall be added to the above.

In retained cuts or on retained fills, the minimum right-of-way required is measured laterally to 2'-0" outside the outside face of the retaining wall. In side cuts, unretained open cuts or fills, the slopes shall include side or surface ditches plus rounding. Desirable right-of-way limit shall be 5'-0" outside the toe of fill slopes or top of cut slopes, subject to variation where existing right-of-way is restrictive and costs for providing additional right-of-way would be excessive.

Lower Limit

The lower limit, when required, shall be defined in a manner similar to that for the upper limit, using a minimum vertical distance of 10'-0" below top of rail, except in retained fill sections. In retained fill sections, the lower limit shall include the structural support system required for fill sections.

5.6.3.2 Aerial Construction (if required)

- The upper limit, where required by local conditions, is delineated by elevations of horizontal planes, stepped as required, co-locating the steps with existing property lines or prominent suitable topographical features. The minimum required vertical distance from top of catenary support structure to the horizontal plane above is 5'-0".
- Minimum lateral limit 5'-0" outside the centerline of each track. Additional easements shall be required for maintenance of and repairs to structures.

- Lower limit, where required by local conditions and/or specifically directed by the UTA, shall be the ground level with specified use restrictions, except where crossing other rights-of-way. For aerial support structures, lower limit shall include support foundation.

5.6.3.3 Storm Drainage and Utilities

- Open ditches: The minimum total width for permanent surface drainage easements shall be governed by local agency requirements, but in no case shall it be less than 6'-0" for paved ditches and channels and 8'-0" for unpaved ditches. Provision of temporary construction easements shall also be considered.
- Underground drainage: Easement widths for underground drainage systems shall be approved by the local agency involved. As a guideline, the minimum easement width is 10'-0" with 2'-0" minimum clearance from outside edge of structure to easement line. Provision of temporary construction easements shall also be considered.
- Utility Easements: Public utility easement widths shall be governed by the agency requirements, but in no case shall it be less than 7'-0".

5.6.3.4 Stations and Park-and-Ride Lots

Right-of-way required for stations and park-and-ride lots shall include space needed for platforms, fare collection, waiting areas, stations ancillary facilities, parking areas, bus stops and the structure.

- In addition to the structural, mechanical, and electrical requirements for space, the requirements for pedestrian and vehicular circulation space shall be observed.

5.6.4 Right-of-Way Information Requirements

5.6.4.1 Curve Data

- All spirals shall be reduced to circular curves at the limits of the right-of-way.
- Circular curves are the only types of curves acceptable for recording purposes.
- Curve data shall be shown on the right-of-way plan sheet in a table of curve data.
- Tangent sections shall be used in lieu of curves to show the limits of the right-of-way when curves are extremely flat (approximately less than 0 degrees, 15 minutes).

5.6.4.2 Continuous Right-of-Way

Although UTA may not require acquisition of public space, all plans shall show the right-of-way envelope as being continuous crossing public as well as private space. Such private space shall be identified.

5.6.4.3 Isolated Right-of-Way

The boundary for all areas supporting all new construction, such as power substations, shall be defined geometrically with ties shown wherever the location is not contiguous to the right-of-way.

5.6.4.4 Street Closings

Separate drawings showing the areas of public property to be closed and utilized for the transit system shall be provided. These drawings shall be prepared in accordance with local requirements.

5.7 Fencing

Generally, access to the light rail tracks shall not be controlled by fencing. However, where tracks are adjacent to school grounds or other high-risk facilities, local access to the tracks may be controlled by fencing. Fencing shall be parallel to the track, forming an open-ended envelope and allowing unrestricted LRT vehicular movement.

Vehicle service, maintenance and storage areas shall be secured by perimeter fencing.

Size, type and length of fencing or barrier shall be as determined by site-specific requirements, or local jurisdictional requirements.

END OF CHAPTER 5.



Utah Transit Authority Light Rail Design Criteria

Chapter 6 Utilities

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 6 UTILITIES

6.1 General

All work required for the relocation, replacement, adjustment, and/or abandonment of existing utility facilities shall be designed in accordance with criteria established by the Utah Transit Authority's LRT Performance Specifications. Potential utility conflicts shall be identified during initial design reviews, with input from municipalities and utility owners; however, Utah Transit Authority, in accordance with this Chapter, shall make the final determination regarding actual utility conflicts. Utilities determined by UTA not to be in conflict will remain in their existing configuration.

These criteria are specific to light rail transit systems operating within city streets and/or state highways, but are referenced as supplemental criteria for light rail transit systems operating within existing railroad corridors.

Requests for future utility crossings are not subject to these criteria, but such utility configuration applications must be approved in writing by the Utah Transit Authority's Manager of Engineering and Construction, and shall comply with Utah Transit Authority's Guidelines for Utility Crossings for existing light rail transit systems. Licenses for crossings will be negotiated through Utah Transit Authority's Real Estate Division.

6.2 Utah Transit Authority LRT RUA

The LRT restricted utility area (RUA) is defined as follows, and shall be the greater of:

- a) Ten feet minimum from edge of utility to centerline of track
- b) The inside of a one to one (1:1) slope, beginning 4 feet from centerline of track, projecting downward to a depth of 10 feet, as measured from the bottom of the rail tie

6.3 Conflicting Utilities

Relocation, replacement, adjustment, protection, and/or abandonment of existing utility facilities shall be required only where an actual conflict exists between the existing utility and the LRT system. Such conflicts shall be identified by Utah Transit Authority, considering the following factors:

- a) Whether the design, construction, maintenance, and/or operation of the proposed LRT will interfere with an existing utility's ability, in its existing location, to provide its intended service; and whether the utility was correctly installed in accordance with the criteria established by the utility owner and authorities having jurisdiction
- b) Whether the design, construction, maintenance, and/or operation of the LRT system will interfere with reasonable access to valves, vaults, air vacuums, pressure reducing stations, manholes, manways, and hand holes, such that the utilities' owner is prevented from operating and/or maintaining its utility in accordance with previously established operation and maintenance criteria
- c) Whether, upon completion of LRT construction, a utility in its existing location creates a potential safety hazard to the general public
- d) Whether the required minimum cover, as defined by reasonable criteria established by the utility owner, is compromised as the result of grade changes for roadways, track, or structures, for the sole benefit of the Utah Transit Authority

- e) Whether soil stresses imposed upon an existing utility by LRT system improvements pose a threat to the integrity of the utility facility, considering the depth and location of utility facility, as well as soil type
- f) Whether the utility in its existing location will interfere with installation or maintenance of LRT system improvements

6.4 Crossing Utilities (Underground)

Existing utilities which cross the LRT RUA, that are determined by the Utah Transit Authority to be in conflict with the LRT, shall be relocated and/or protected by UTA in accordance with the following criteria.

Any pressurized liquid line which crosses the RUA, including but not limited to transmission and distribution water mains, water service laterals greater than 2 inches in diameter, fire protection service lines and pressurized sanitary sewer main lines, shall be installed within a solid steel casing, or other casing material type as determined to be in the best interest of Utah Transit Authority. If split steel casings are installed, all joints, seams, gaps, and interfaces between casing sections shall be fully welded to ensure 100% containment of the casing pipe, such that carrier pipe failures are revealed at either end of the casing pipe, outside the RUA. The replacement utility shall be located such that the top of the casing is a minimum of 6 feet deep, as measured from the bottom of the track ballast to top of casing. The casing ends shall extend beyond the RUA as measured from the bottom of the track ballast, at a 45 degree angle from the horizontal, to the casing ends. Casings shall not be required for any gravity systems, including storm drain and sanitary sewer mains or laterals, or any other lines containing non-pressurized liquids.

6.4.1 Water Services to Residents and Businesses

Where roadway widening, or distribution water main relocations result in the disruption of water service to residents and/or businesses, existing water meters shall be relocated in accordance with reasonable criteria established by the utility owner. Splices in water service laterals up to 2 inches in diameter shall be allowed, provided that splicing material, size, and type match existing laterals, and approved fittings are installed in accordance with the manufacturer's recommendations. For lateral water service connections to relocated distribution water mains, corporation stops and service saddles shall be provided by the Utah Transit Authority's General Contractor.

6.4.2 Communication, Natural Gas, and Electrical Lines

Existing utilities shall be lowered in place or looped as required, and sections of HDPE split casings installed such that existing conduit is continuous, and installed to facilitate future removal as necessary.

6.5 Crossing and Parallel Utilities (Overhead)

Clearances from the overhead distribution system shall be in conformance with the requirements of Chapter 13 of this Design Criteria, the National Electric Code, the utility owners, American Railway Engineering & Maintenance-of-Way Association (AREMA), the Public Service Commission, and any other authority having jurisdiction.

Transmission and distribution electrical or communication lines attached to poles in accordance with previously established lease agreements shall be relocated and adjusted in place or looped underground, as determined to be in the best interest of the Utah Transit Authority.

6.6 Parallel Utilities (Underground)

Utilities located within the LRT RUA, that contain a pressurized liquid and determined to be in conflict, shall either be replaced with a replacement utility located outside the RUA as required, to connect back to its existing line, or installed within a steel casing, steel split casings, or other casing material as determined to be in the best interest of the Utah Transit Authority. If reasonable access to hand-holes, manholes, vaults, or access man-ways is not compromised, the utility may remain in its existing location, as determined by the Utah Transit Authority.

Gravity systems shall be designed in accordance with utility owners' established criteria, and installed between manholes at a depth such that the original flowline is maintained and lateral connections from residences and businesses, or curb inlet boxes shall meet minimum grade requirements.

Utilities located outside the LRT RUA, and determined by the Utah Transit Authority to be in conflict with roadway widening, including hand-holes; gas and electrical vaults; and communication vaults, lines, and cables previously located within park strips, mow strips, or behind sidewalks, and as a direct result of LRT construction are now located in roadways or sidewalks, shall be modified in accordance with the following.

- a) Fiberglass communication hand holes located in a roadway shall be replaced with concrete hand holes which comply with HS-20 loading requirements. If their new location is sidewalks, existing fiberglass hand holes shall be adjusted to finished grade such that no tripping hazard is present.
- b) Concrete vaults that must be lowered, (if allowed by the utility owner and sufficient head room clearance is available), shall have their top deck saw-cut and removed, and a replacement concrete deck cast to match the new roadway or sidewalk grades.
- c) Fiber optic communication lines shall be lowered in place, utilizing available slack. Split casings shall be installed such that existing conduits are continuous.
- d) Communication cables shall be lowered in place if possible, or looped between existing pedestals to achieve sufficient depth.
- e) Risers shall be adjusted and manholes ringed to match finished grade.

6.7 Abandoned Utilities

6.7.1 *Abandoned Transmission, Distribution Water, Sanitary Sewer, and Storm Drain Lines*

- a) Any abandoned piping, resulting from the resolution of a previously conflicting utility, shall be abandoned in place. Abandoned pipe larger than 8 inches in diameter shall have the pipe ends plugged with concrete to mitigate any conduit effects, and potential future settlement associated with the ground water movement.
- b) Abandoned manholes, resulting from the resolution of a previously conflicting utility shall be abandoned in place. The ring and cover shall be returned to the municipality having jurisdiction. The top manhole section shall be removed to a minimum depth of 3 feet below top of sub-grade. The interior influent and effluent piping shall be plugged with concrete and the remaining sections backfilled and compacted in accordance with the municipalities established criteria.

6.7.2 *Abandoned Communication, Gas, and Electrical Lines*

All abandoned communication lines and gas and electrical lines shall be abandoned in place.

6.8 Corrosion Protection

Corrosion protection shall be sole responsibility of the utility owner. If UTA is performing any work related to the utility and if the utility owner deems that corrosion protection is required, it is the responsibility solely of the utility owner to specify to UTA its requirements for corrosion protection. UTA shall not be responsible in any manner whatsoever for the adequacy of such corrosion protection. Designers should refer to Chapter 16 for Corrosion Protection of underground utilities.

END OF CHAPTER 6.



Utah Transit Authority Light Rail Design Criteria

Chapter 7 Structural

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 7 STRUCTURAL

7.1 General

This chapter establishes the basic design criteria for light rail structures, including bridges, stations, retaining walls, buildings, catenary structures, drainage structures, construction structures, and miscellaneous structures. All applicable structural criteria are contained herein, excluding the structural criteria for the overhead contact system (OCS) which is provided in Section 12.5. Where special design cases are encountered that are not specifically covered in these criteria, the designer shall determine the applicable technical sources for the design criteria to be used, and obtain the approval of the UTA Light Rail Project Director prior to use.

All design of structures constructed as part of the LRT System shall comply with these criteria to the maximum extent possible. Where not covered by design criteria, design shall comply with applicable municipal, county, state, and federal regulations and codes listed below.

Clearance requirements for centerlines of LRT tracks to all adjacent structures above top of rail are discussed in Chapter 3 of this manual. The designer is reminded that these requirements must be adhered to in the design of all structures including bridges, stations, and retaining walls; therefore, no additional references to clearances are made in this chapter.

7.2 Design Codes, Manuals, and Specifications

The following codes, manuals, and specifications, in the most current version, shall be utilized in the design of structures as set forth in this chapter.

7.2.1 Building Codes

All LRT facility buildings shall be designed in accordance with local municipal law or, in the absence of such law, shall be in accordance with the most current International Building Code (IBC) for the construction of rail transit building facilities.

7.2.2 Other Design Criteria

For bridges and aerial structures that support LRT loadings, the design requirements of applicable LRT loading (see Section 7.4) and the current edition of AASHTO *LFRD Bridge Design Specifications* with interim specifications shall be used except as otherwise noted herein. When AASHTO is not applicable, the current edition of American Railway Engineering and Maintenance-of-Way Association (AREMA) shall be used.

For bridges that support railroad loadings, the design requirements of the applicable railroad shall apply. In the absence of such requirements, the current edition of American Railway Engineering and Maintenance-of-Way Association (AREMA) shall be used.

For bridges that support highway loading, the design requirements of the applicable jurisdiction shall be used. In the absence of such requirements, the current edition of AASHTO shall be used.

For concrete, reinforced concrete, precast concrete, and prestressed concrete structures other than bridges subjected to LRT, railroad or highway loading, the *Building Code Requirements for Reinforced Concrete* shall be used.

For structural steel structures other than bridges subjected to LRT, railroad, or highway loading, the most current edition of *Manual of Steel Construction* from the American Institute of Steel Construction, hereinafter referred to as the AISC Specification, shall be used.

For timber structures and bridges subjected to railroad or LRT loading, the current edition of AREMA shall be used.

For welded structures, the current edition of *Structural Welding Code* shall be used to design welded structures not covered by the above.

For drilled piers and caissons, the current edition of *Suggested Design and Construction Procedures for Pier Foundations* shall be used.

For the overhead power distribution system, the design of support structure shall be in accordance with Chapter 12 of this manual.

For cast iron structure, the current edition of *The Gray Iron Casting Handbook* shall be used.

For cold-formed steel structures, the current edition of *The Cold-Formed Steel Design Manual* shall be used.

For aluminum structures, the current edition of the *Aluminum Design Manual* shall be used.

7.3 Materials

7.3.1 General

All materials shall conform to the applicable specification and codes listed in Section 7.2. If significant economies can be achieved by the use of different material than those specified in this manual, while providing at least the same level of performance and durability, the designer may substitute alternate material standards after receiving written approval from the UTA Light Rail Project Director.

7.3.2 Fire Protection of Structures

All materials, including thermal and acoustical insulation of ductwork and piping, shall be inorganic in composition and shall contain no organic binder. All material other than concrete, masonry, tile, metals, and similar materials shall have a certified classification of non-combustibility as defined by ASTM E136, *Determining Non-Combustibility of Elementary Materials*, modified by the further requirements that no flaming will be permitted during any portion of the test period. Flame-proofing of the material is not acceptable. In cases where no suitable material conforms with these requirements, very minor quantities of an accessory material may be permitted if prior approval in writing is obtained from the UTA Light Rail Project Director.

Underwriters' Laboratories, Inc. label or listing, satisfactory test results from the National Bureau of Standards or certified report from an approved testing laboratory will be required to indicate that fire hazard ratings for material proposed for use conform to the above.

7.3.3 Structural Steel

- Consideration shall be limited to the following types of structural steel:
- Structural Steel—For normal use: ASTM A36.

- High Strength Structural Steel—For uses requiring higher strength steels or where economically justifiable: ASTM A242, A440, A441, A514, A588, A572.
- Connections—Shop connections shall be welded unless otherwise shown on the contract drawings. All welding shall be in accordance with the current code or specifications of the American Welding Society, D1.1.
- Field connections shall be designed for high strength bolts unless otherwise shown on the contract drawings. High strength bolts shall be ASTM A325 or A490 bolts.
- Other types may be used only with the approval of the UTA Light Rail Project Director.

7.3.4 Reinforced and Prestressed Concrete

7.3.4.1 Cements

Portland cement shall be used in accordance with ASTM C150.

Type II Portland cement shall be specified for all concrete construction unless otherwise noted on the contract drawings or specifications.

7.3.4.2 Reinforcing Steel

Reinforcing steel other than for prestressed concrete shall be ASTM A615, Grade 60, unless otherwise indicated. Stirrups shall be Grade 40 or 60.

For prestressed concrete, the grade of steel shall be as required by the design. Unbonded and ungrouted prestressing steel shall not be used.

Reinforcing bar details shall be as per ACI 318 and the current edition of “Details and Detailing of Concrete Reinforcement” in the *ACI Detailing Manual*, with revisions. Provisions for the distribution of flexural reinforcing bars for concrete members shall be in accordance with AASHTO.

7.4 Serviceability

For LRT structures that include a pedestrian component, $L/800$ bridge deflection and 50 in/sec^2 acceleration should be used for design.

7.5 Loads and Forces

7.5.1 General

Structures or parts of structures subjected only to LRT loadings or to LRT and railroad loadings shall be designed considering loads due to system-wide elements such as electrification, signalization, communication equipment, and the following other loads and forces:

- Dead load (DL)
- Live load (LL)
- Derailment load (DR)
- Impact (I)
- Centrifugal force (CF)
- Rolling force (RF)
- Longitudinal force (LF)

- Horizontal earth pressure (E)
- Hydrostatic pressure and buoyancy (B)
- Wind load on structure (W)
- Wind load on live load (WL)
- Stream flow pressure and flooding (SF)
- Shrinkage and creep forces (S)
- Thermal force (T)
- Ice pressure (ICE)
- Differential settlement

The loading criteria to which the structures are designed shall appear on the structural drawings. When required by design conditions, concrete placing sequence shall be indicated on the plans or in the supplementary conditions.

7.5.2 Dead Load (DL)

The dead loads consist of the actual weight of the structure including permanently installed track work, walls, floors, partitions, roofs, electrification, safety walks, pipes, conduits, cables, utilities, services, and all other permanent construction and fixtures. Since dead load stresses are always present, the structure should be so designed as to sustain them at all times.

The dead load should be computed from the weights of the material composing the structure and its permanent fixtures. The approximate unit weights of material normally used in construction are shown in Table 7-1. A specific check should be made as to the actual weight where a variation might affect the adequacy of the design, or in cases where the construction may vary from normal practice. The dead load of the catenary support system for electrification shall be determined by the systems consultant.

Table 7-1: Unit Weight of Building Materials

Aluminum Alloys	175	pcf
Asphalt mastic, bituminous macadam	150	pcf
Ballast, crushed stone	120	pcf
Ceilings, plaster board, unplastered	3	psf
gypsum, ceiling tile 2", unplastered	9	psf
pressed steel	2	psf
Ceramic glazed structural facing tile, 4"	33	psf
Floors, gypsum floor slab, per inch	5	psf
asphalt mastic	5	psf
ceramic tile, on 1" mortar bed	23	psf
terrazzo, 1" on 1/2" mortar bed	18	psf
marble, 1" on 1/2" mortar bed	20	psf
linoleum, 1/4"	2	psf
maple, 7/8" on sheathing, 2" cinder fill, no ceiling	18	psf
oak, 7/8" on sheathing, wood joists at 16" centers, no ceiling	11	psf
Glass	160	pcf
Gravel, sand	120	pcf
Iron, cast	450	pcf
Partitions, plaster, 2", channel stud, metal lath	20	psf
plaster, 4", channel stud, metal lath	32	psf
hollow plaster, 4", metal lath	22	psf
gypsum block, solid, 3" both sides plastered	19	psf
gypsum block, hollow, 5" both sides plastered	22	psf
marble wainscoating, 1"	15	psf
steel partitions	4	psf
ceramic glazed structural tile, 4"	33	psf
Rails and fastenings, per track (2 rails)	200	plf
Roofs, roofing felt, 3-ply and gravel	5.5	psf
roofing felt, 5-ply	6.5	psf
sheathing, 3/4" thick	3.5	psf
Steel	490	pcf
Timber, untreated	48	pcf
treated	60	pcf
Walls, brick solid, per inch	10	psf
terra cotta tile, 4", plastering—add	25	psf
terra cotta tile, 8", 5 psf per side	33	psf
terra cotta tile, 12"	45	psf
glass, structural, per inch	15	psf
windows, frame, glass, sash	8	psf
stone, 4"	55	psf
steel sheet, 14 gauge	3	psf

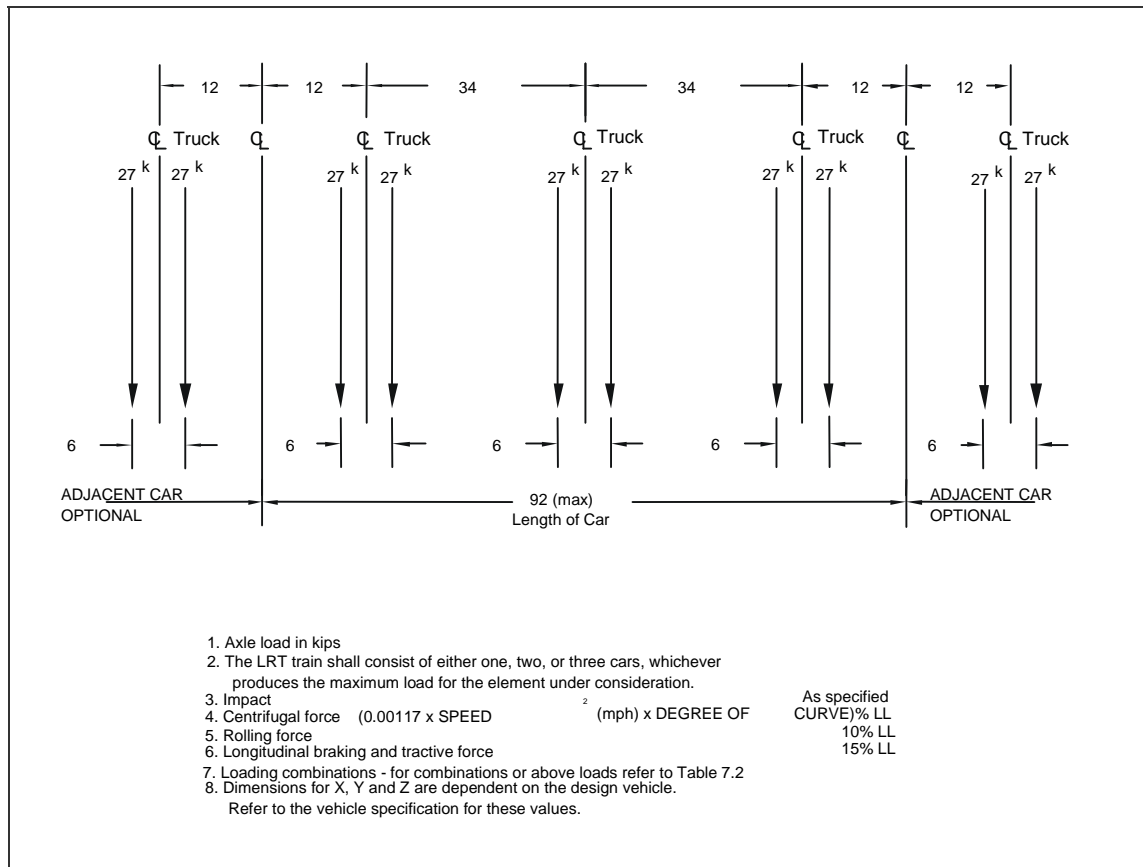
7.5.3 Live Load (LL)

Live load shall consist of any non-permanent loads including the weight of machinery, equipment, sorted materials, persons, transit vehicles, freight train, or other moving objects, construction loads, and loads due to maintenance operations.

7.5.3.1 Light Rail Transit Vehicle Design Loading

See Figure 7-1 for car dimensions and weights. Any combination of train lengths and loading which produces the critical design loading shall be used for structural design.

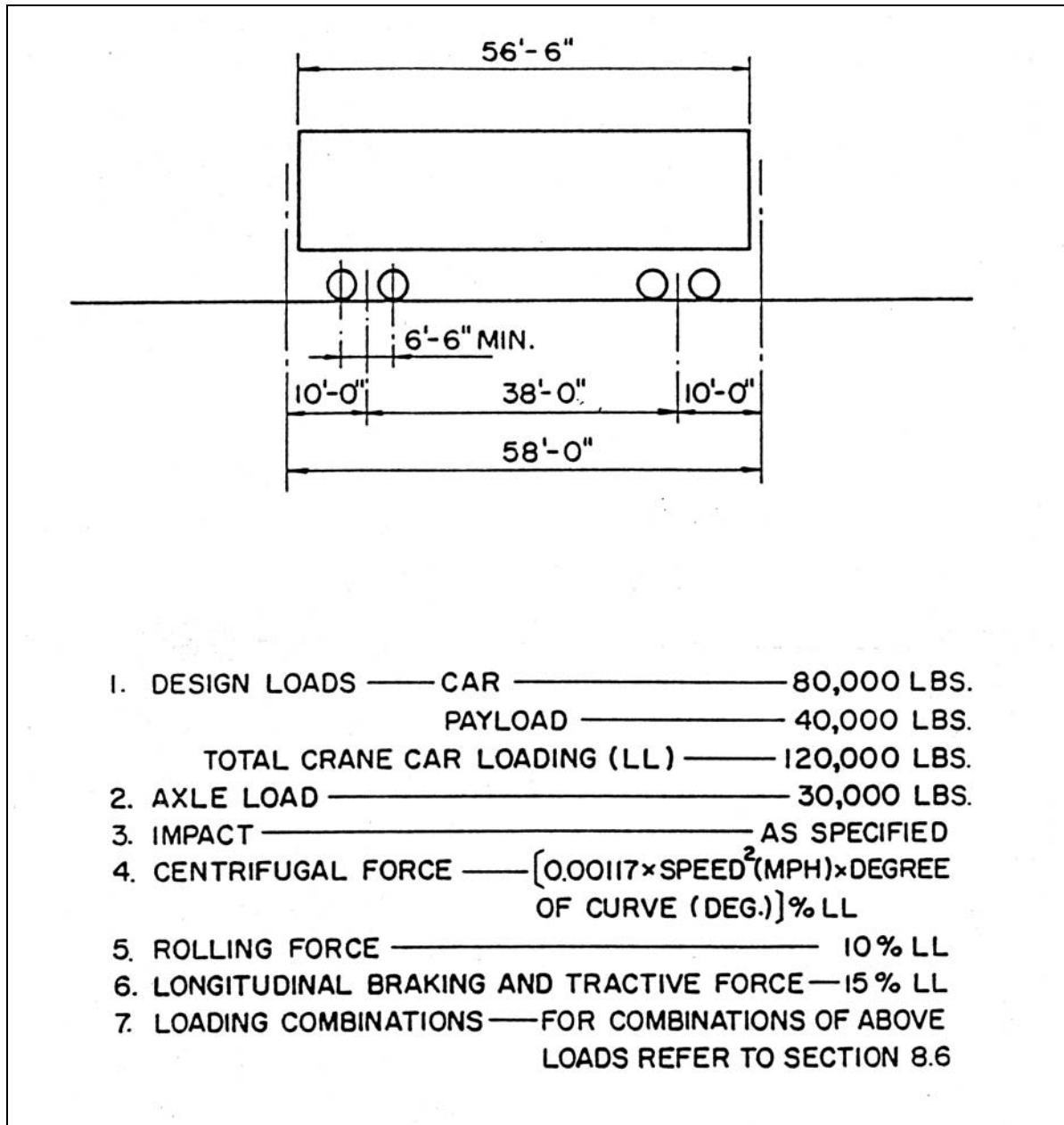
Figure 7-1: Light Rail Vehicle Design Loading (LRV Vehicle Only)



7.5.3.2 Crane Car Design Loading

See Figure 7-2 for car dimensions and weights. Use 75% of car weights for structural design.

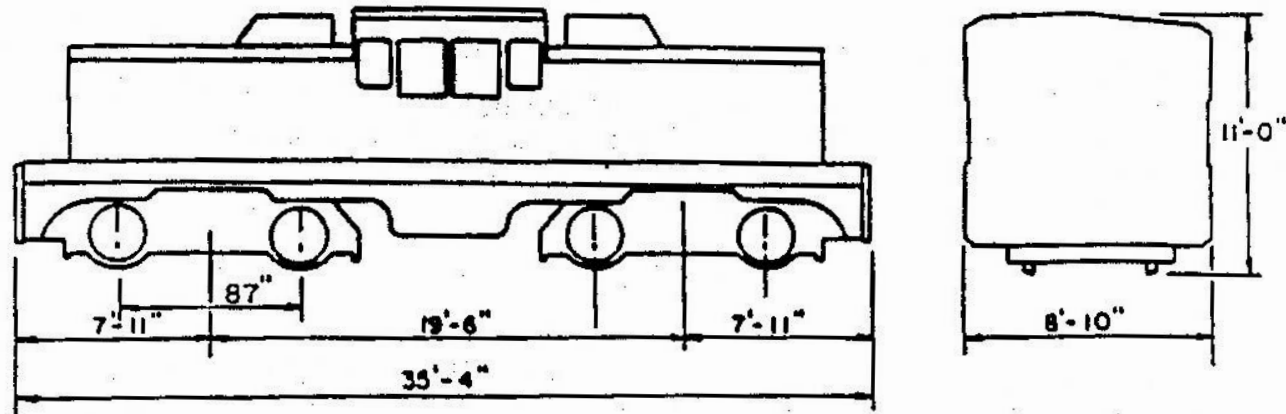
Figure 7-2: Crane Car Design Loading



7.5.3.3 Locomotive and Work Train Design Loading

See Figures 7-3 through 7-6 for car dimensions and weights. Subject to concurrence with the UPRR, use 75% of car weights for structural design.

Figure 7-3: Locomotive (CR8) Design Loading



1. DESIGN LOAD ————— 122,000 LBS.
2. AXLE LOAD ————— 30,500 LBS.
3. IMPACT, CENTRIFUGAL FORCE,
ROLLING FORCE, BRAKING
AND TRACTIVE FORCE AS
PER FIGURE 7.1

Figure 7-4: Work Train (Type A) Design Loading

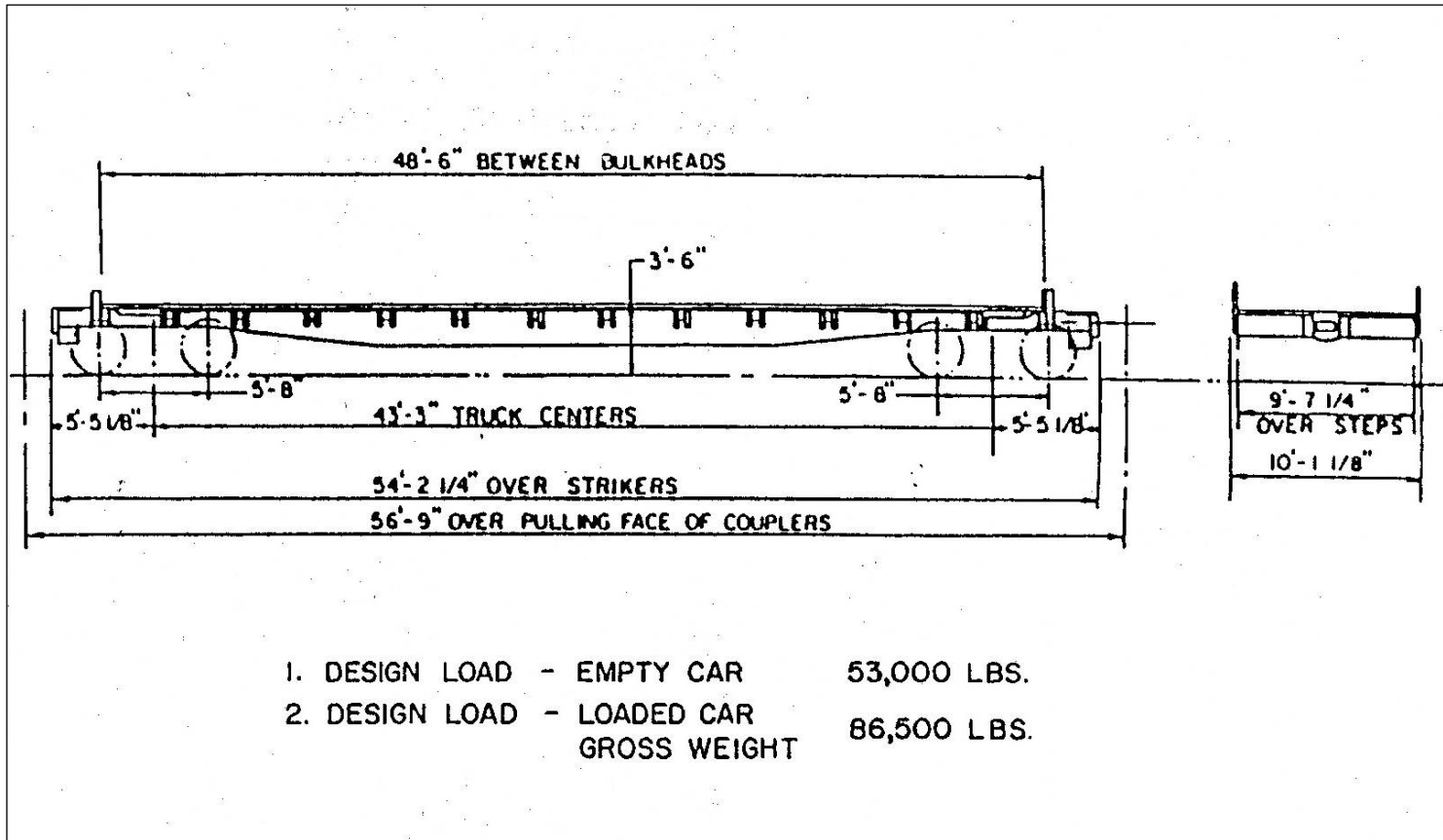


Figure 7-5: Work Train (Type B) Design Loading

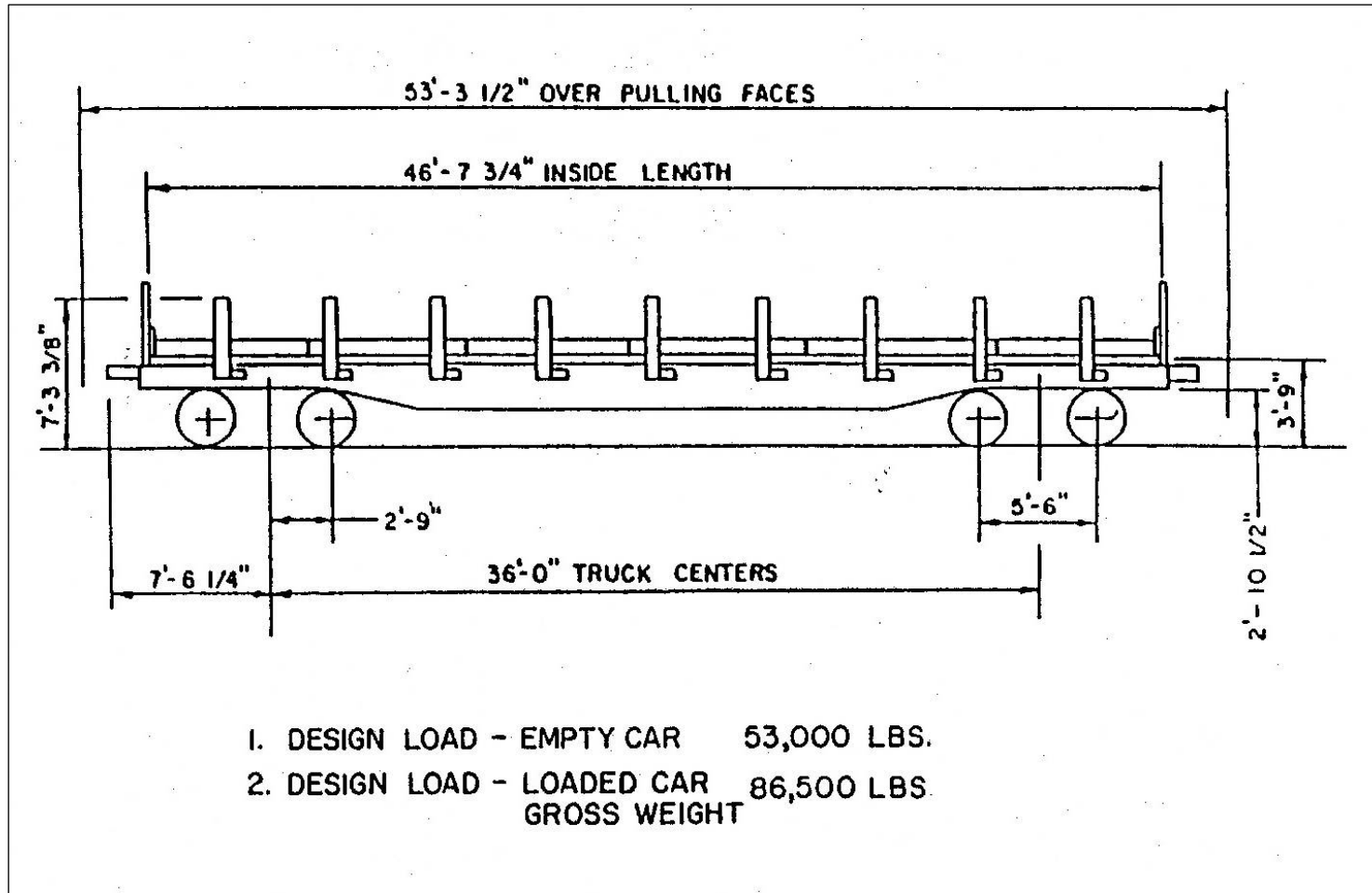
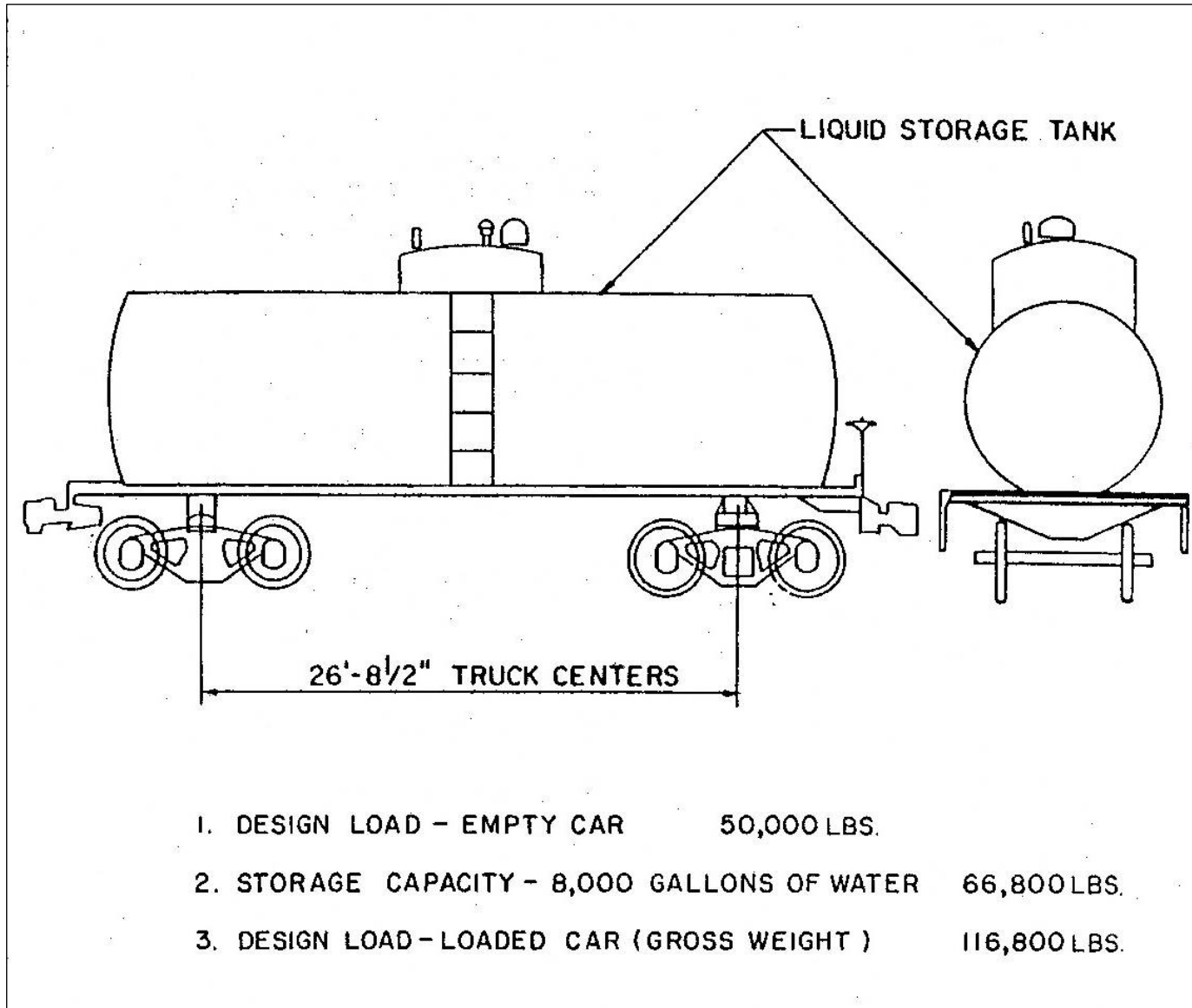


Figure 7-6: Work Train (Type C) Design Loading



7.5.3.4 Freight Train Loading

Railroad LL shall be Cooper E80 loads and as specified in American Railway Engineering and Maintenance-of-Way Association (AREMA), unless otherwise specified by the UTA Light Rail Project Director.

7.5.3.5 Pedestrian Areas

Station platforms, pedestrian ramps, mezzanines, and other pedestrian areas with no access for cars and trucks shall be designed for a uniform load of 150 psf, and the pedestrian areas with access for cars and trucks shall be designed for a minimum uniform load of 250 psi. Stairways shall be designed for a uniform load of 100 psf or a concentrated load of 300 pounds on the center of stair treads, whichever is critical.

7.5.3.6 Storage Space and Machinery Rooms

Electrical equipment rooms, service rooms, storage space, and machinery rooms shall be designed for a uniform load of 250 psf, to be increased if storage or machinery loads dictate.

7.5.3.7 Railings

Railings in station platforms shall be designed for a horizontal force of 150 plf and a vertical force of 100 plf at the top acting simultaneously in each longitudinal member. Railings in other places of public assembly shall be designed in accordance with local codes. Railings in equipment rooms and working areas shall be designed for a force of 200 pounds applied in any direction at any point. Rail members located more than 5'-0" above the walkway are excluded from these requirements.

7.5.3.8 Post

Post shall be designed for a horizontal force of WL where W is the maximum uniform horizontal force on each railing and L is the post spacing.

7.5.3.9 Service Walks

Service walks shall be designed for a uniform load of 85 psf.

7.5.4 Derailment Load (DR)

The vertical derailment load of LRVs shall consist of the LRV's maximum vehicle weight multiplied by an impact factor. An impact factor of 100% shall be used for the deck design (multiply vehicle weight by 2.0), and an impact factor of 30% shall be used for the girder and applicable substructure design (multiply wheel load by 1.3). The derailment load shall be as follows:

$$DR = LL + ID, \text{ where } ID = \text{Derailment impact}$$

The derailment load shall be applied to all elements of the superstructure and to those elements of the substructure as required by Section 7.5.5. The derailment load shall be assumed to act anywhere on the deck within the curb lines with their longitudinal axis parallel to the track.

When checking any component of superstructure to substructure that supports two or more tracks, only one train on one track shall be considered to have derailed, with the other track being loaded with a stationary work train, including locomotives, cranes, flats, etc., or another LRV vehicle, ready to receive passengers from the derailed vehicle. The design load used shall be the greatest of these loadings.

All elements of the structure shall be checked assuming simultaneous application of all derailed wheel loads. The reduction of positive moment in continuous slabs due to derailed wheel loads in adjacent spans shall not be allowed.

7.5.5 Impact (I)

Impact loads are statically equivalent dynamic loads resulting from vertical acceleration of the LL.

7.5.5.1 Impact Considerations

Impact considerations for aerial structures supporting railroad train loading and/or light rail transit loading shall meet the requirements as follows:

- Impact shall be applied to the superstructure and generally to those members of the structure that extend down to the top of footings. The portion above the ground line of concrete or steel piles rigidly connected to the superstructure as in rigid frame or continuous design is included. Impact shall not be considered for abutments, retaining walls, wall-type piers, piles, footings and service walks, except for the portion of piles rigidly connected to the superstructure.
- Vertical impact for structures supporting railroad common freight carrier train and light rail transit loadings is covered under Section 7.7. The impact force shall be applied at the top of low rail, distributed the same as outlined for the axle loads.
- In addition to the vertical impact, a horizontal impact (or nosing) force (NF) equal to 10% of railroad train or light rail transit design load shall be applied. This force shall be equally distributed to the individual axles of the vehicle and shall be assumed to act in either direction transverse to the track at the top of the low rail.
- Structures supporting special vehicles, such as moving equipment, or other dynamic loadings that cause significant impact shall conform to the building code of the locality or, if not covered by code, shall be considered individually using the best technical information available.
- Impact shall not be considered for stairways, mezzanines, station platforms, or other pedestrian areas.

Impact loads shall be considered in the LRT design as described below.

Vertical impact loads for LRT-only aerial structures shall be considered in the design as follows:

- Impact force for the design of simply supported longitudinal girders
- $I = 30\%$ of the total light rail transit vehicle or freight car loading

For structures with longitudinal girders continuous over supports, including cantilever systems:

- $I = 40\%$ of the total light rail transit vehicle's loading for girders in regions of negative bending and for the supports where the girders are continuous
- $I = 30\%$ of the above loading for continuous girders in regions of positive bending and for the supports where the girders are discontinuous
- These constant vertical impact factors apply where the unloaded natural frequency of first mode of vibration of the longitudinal girders is not less than 2.5 cycles per second

Vertical impact loads for structures supporting freight trains shall be in accordance with AREMA.

7.5.6 Centrifugal Force (CF)

7.5.6.1 LRT

Centrifugal force shall be determined in accordance with AREMA.

7.5.6.2 Railroad

The centrifugal force shall be according to the requirements of AREMA.

7.5.7 Rolling Force (RF)

A force equal to 10% of the light rail transit loading per track shall be applied downwards on one rail and upwards on the other, on all tracks. The rolling force shall be considered in a similar fashion as the longitudinal force is considered in the loading combinations of AASHTO Article 3.22.1.

7.5.8 Longitudinal Force (LF)

7.5.8.1 LRT

Refer to AREMA for LRT longitudinal force.

7.5.8.2 Railroad

Longitudinal force shall be in accordance with latest edition of American Railway Engineering and Maintenance-of-Way Association (AREMA).

7.5.9 Horizontal Earth Pressure (E)

Structures which retain earth shall be designed for side pressure due to earth abutting against the structure and load surcharges resting on abutting earth. Consideration shall be given to multi-layered effects where substantial differences in soil properties occur over the depth of the structures.

Light rail transit loading may be assumed as a uniform surcharge load equal to 3 additional feet of earth.

Live and dead loads from adjacent foundations of structures shall be considered in computing horizontal pressures.

Where railroad loading occurs, the surcharge shall be determined by American Railway Engineering and Maintenance-of-Way Association (AREMA).

7.5.10 Hydrostatic Pressure and Buoyancy (B)

Hydrostatic pressure and buoyancy shall be determined in accordance with AASHTO.

7.5.11 Wind Load on Structure (W)

The bridge structures shall be designed to withstand wind loads of uniform pressure acting upon the superstructure and substructure as specified in this section.

Wind loading on catenary shall be considered in the design of both superstructure and substructure elements. Loads (magnitude and location) shall be determined by the systems consultant.

The forces and loads given herein are based on a wind velocity of 80 miles per hour, as recommended in the IBC.

7.5.11.1 Wind Load on Superstructure

The wind load on the superstructure shall be determined in accordance with AREMA, AASHTO, or IBC as applicable.

7.5.11.2 Wind Load on Substructure

The wind load on the substructure shall be determined in accordance with AREMA, AASHTO, or IBC as applicable.

7.5.12 Wind Load on Live Load (WL)

Provision shall be made in the design of the superstructure for a transverse and longitudinal horizontal wind load as specified in this section.

These loads apply to the design of substructure elements supporting a single track. For the design of substructure elements supporting two tracks, these loads shall be increased by 30% when both tracks are loaded. This factor accounts fully for shielding effect of vehicle-on-vehicle as the two trains run alongside each other.

Design shall include a transverse horizontal wind load of 300 p/f and a longitudinal horizontal wind load of 75 p/f for the entire length of track supported by the element being designed. The transverse load shall be applied to the train as concentrated loads at the axle locations, in a plane 8 feet above the top of the low rail and normal to the track. The longitudinal force shall be applied to the rails and superstructure as a uniformly distributed load in a horizontal plane at the top of low rail.

7.5.13 Force from Stream Current, Floating Ice, and Drift

7.5.13.1 Stream Flow Pressure and Flooding (SF)

Local flooding may add load to structures in the flood plain. Design of the structures should make allowance for this loading as required by the particular type of structure and the conditions affecting each location. Anticipated flood elevations shall be determined by a study of official flood records. SF shall be included in the design of aerial structures where applicable. All piers and other portions of structures that are subject to flood forces shall be designed in accordance the requirements outlined in AASHTO Section 3.18.

7.5.13.2 Force of Ice on Pier (ICE)

The force of ice on pier shall be determined in accordance with AASHTO.

7.5.14 Shrinkage and Creep Forces (S)

Shrinkage and creep forces shall be determined in accordance with AASHTO.

7.5.15 Thermal Force (T)

Provision shall be made for stresses and deformations resulting from temperature changes described in this section.

7.5.15.1 Expansion Coefficients

The expansion coefficients are as follows:

Concrete

Temperature rise: 35 °F

Temperature fall: 45 °F

Coefficient of expansion: 0.0000060 inch/inch/°F

Steel

Temperature rise: 50 °F

Temperature fall: 80 °F

Coefficient of expansion: 0.0000065 inch/inch/°F

Rail

Temperature rise: 70 °F

Temperature fall: 70 °F

Coefficient of expansion: 0.0000065 inch/inch/°F

7.5.15.2 Direct-Fixation Temperature Forces

For direct fixation track, provision shall be made for transverse and longitudinal forces due to temperature variations in the rail. These forces shall be applied in a horizontal plane at the top of the low rail.

Transverse Force

For equal adjacent spans, the transverse force in pounds per span of structure per rail shall be determined by the following formula:

$$T = 2 \cdot E \cdot A \cdot C \cdot \Delta T \cdot \sin(\frac{1}{2}) \cdot (L/R) \cdot (180/\pi) \text{ [lbs]}$$

where

- E = Young's modulus of rail (psi)
- A = rail cross-sectional area (sq. in)
- C = coefficient of expansion of rail
- ΔT = temperature differential (°F)
- L = span length along curve (ft)
- R = curve radius (ft)
- π = 3.14159

For unequal adjacent spans, the transverse force must be resolved into components parallel and perpendicular to the pier at each rail fastener and then summed. See Figures 7-7 and 7-8.

Figure 7-7: Lateral Restraint of Transverse Force in Rail by Single Fastener

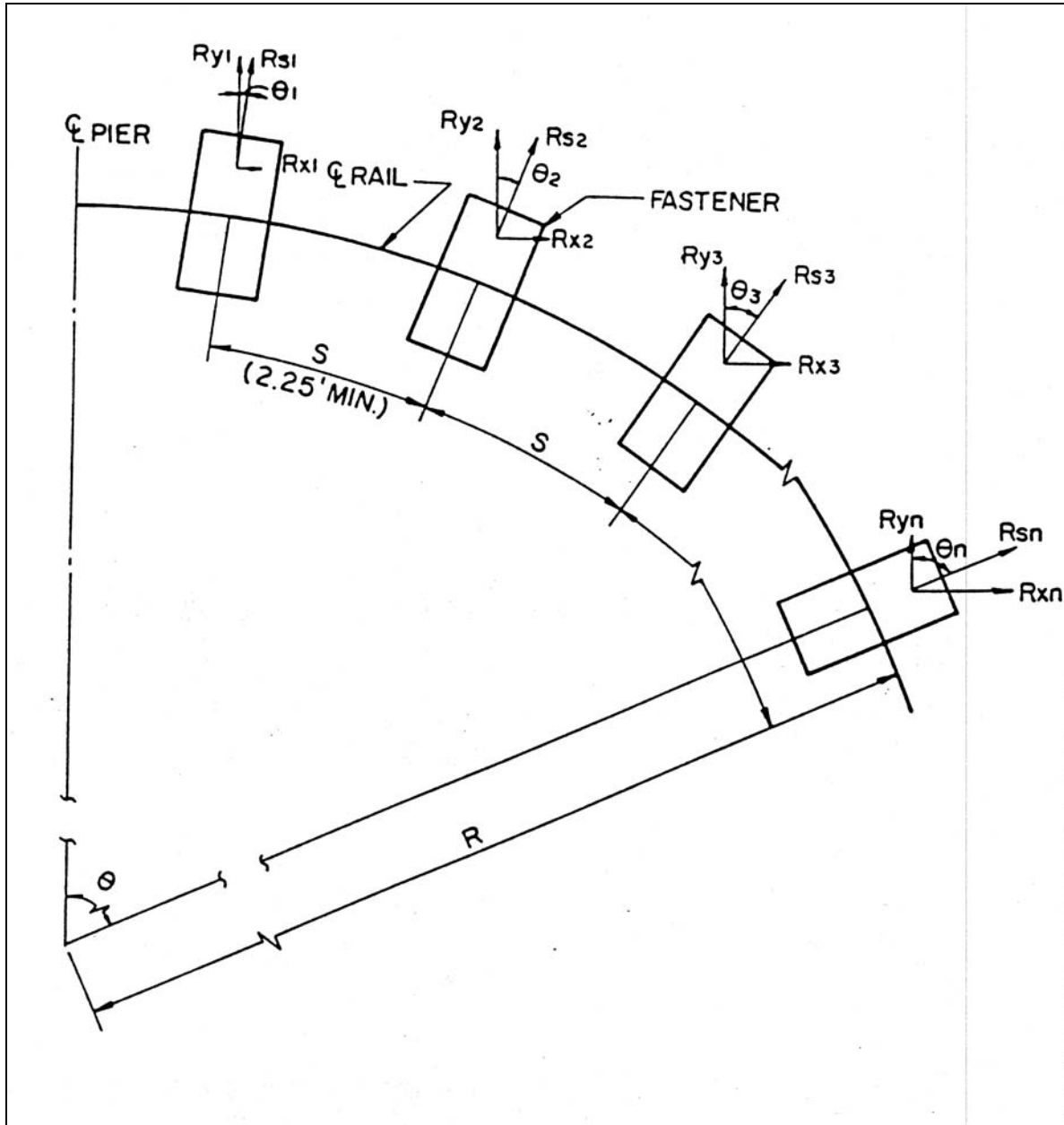
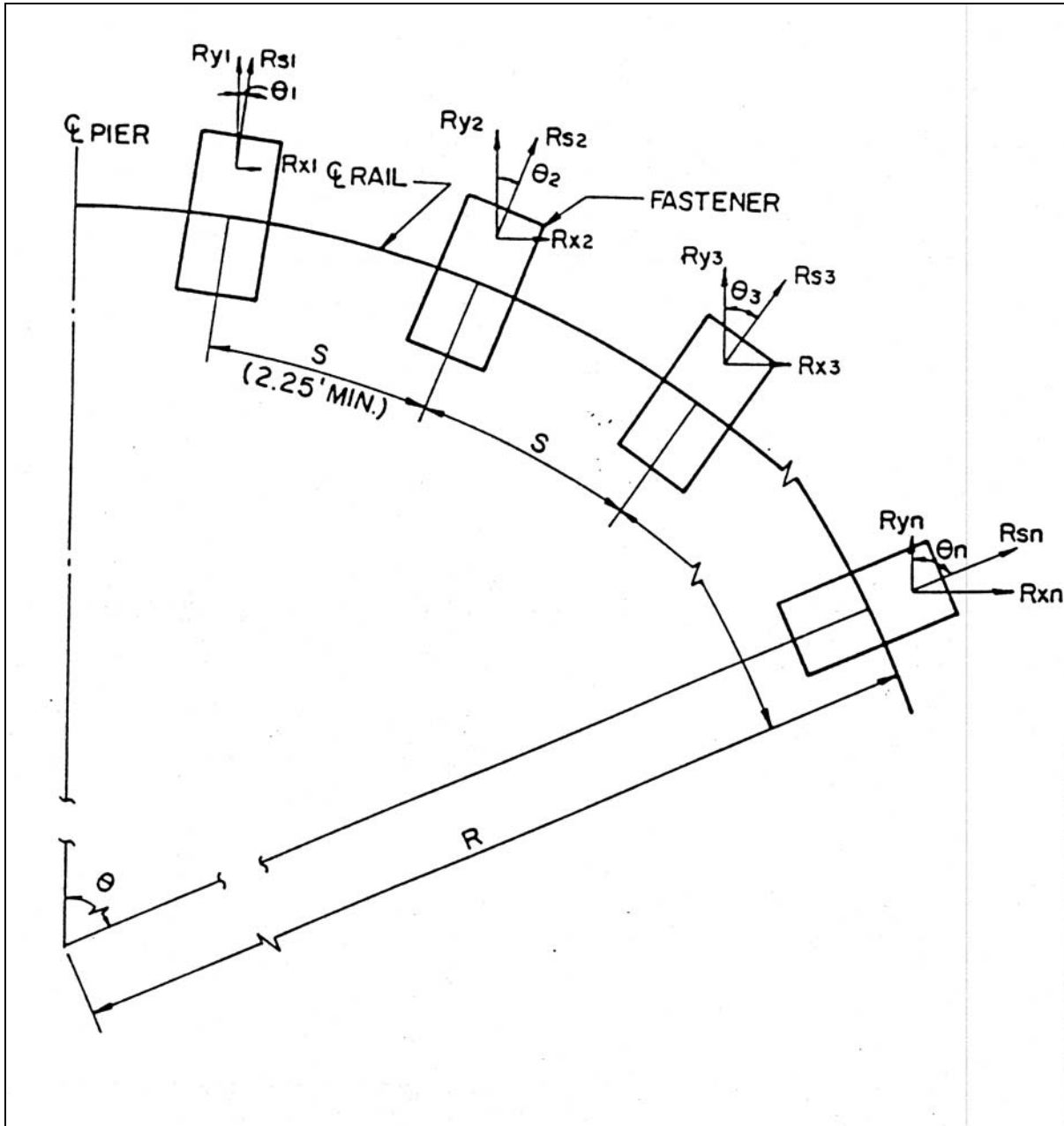


Figure 7-8: Lateral Restraint of Transverse Force by Fastener



Longitudinal Force

The longitudinal force per structure per rail shall be determined by the following formula, in lieu of more exact coefficient of friction and breakaway load values for specific clips:

$$T = 0.65 \cdot P \cdot L$$

where

P = vertical claming force of rail fastener per linear foot

L = average span length of two adjacent spans (ft)

For curved track, L is measured along curve.

7.5.15.3 Thermal Forces

Thermal forces resulting from the temperature variations in the overhead catenary system shall be considered. Loads shall be determined by the systems designer.

7.5.16 Differential Settlement

Load(s) induced on the structures by tolerable differential settlement shall be considered in the loading combination. Consider this load similar to shrinkage and thermal forces. The tolerable differential settlement shall be established in accordance with Section 7.7.7 of these criteria.

7.5.17 Earthquake

Design bridges supporting LRT only according to UDOT Seismic Design Criteria. Design bridges supporting freight according to AREMA seismic provisions. If a bridge supporting freight crosses UDOT right-of-way, design shall satisfy both AREMA and UDOT Seismic Design Criteria.

7.6 Earth Retaining Structures

7.6.1 General

This section establishes criteria for the design of abutments, wingwalls, retaining walls, and other earth retention structures which are required by the construction of the LRT system.

Earth retention structures which are railroad-owned or which retain a railroad trackway shall be designed in accordance with criteria described in American Railway Engineering and Maintenance-of-Way Association (AREMA) as supplemented by criteria of the railroad owner.

Structures which are owned by local governments or other owners shall be designed in accordance with criteria specified by each owner unless specified approval of the use of other criteria contained herein is obtained from the owner.

7.6.2 Reinforced Concrete Retaining Walls

Retaining walls shall be designed on the basis of specific soils characteristic of the institute and backfill materials.

7.6.3 Live Load Considerations

The horizontal pressures acting on these structures shall be in accordance with Section 7.5.9 of these criteria.

7.6.4 Types of Retaining Walls, Abutments, and Wingwalls

In general, retaining walls shall be of the reinforced concrete cantilever type. Other types of retaining walls may be used if proven cost effective and practically feasible within the site constraints.

7.7 Design of LRT Structures

7.7.1 General

The criteria set forth in this section pertains specifically to the design of new bridges and rehabilitation of existing bridges carrying freight trains and/or LRVs.

7.7.2 Loads and Forces

Where applicable, loads and forces listed in Section 7.5 shall be used for the design of light rail transit aerial structures. Other loads and forces to be considered include the elements in this section.

7.7.2.1 Dead Load (DL)

The dead load of aerial structures shall consist of the gravity loads of the basic supporting girders and structure.

Trackwork and appurtenances and secondary elements supported by the structure and added after construction of the basic structure shall be considered as superimposed dead load. In areas of tie and ballast construction, the weight of the ties and ballast shall also be considered as superimposed dead load.

7.7.2.2 Live Load (LL)

Refer to Section 7.5 for live load magnitudes. Light rail transit vehicle wheel loads shall be distributed as explained below.

Where a wheel load is transmitted to a slab through rail mountings placed directly on the slab, the wheel load shall be assumed to be uniformly distributed on the slab over a 3'-0" length of rail and a 1'-2" width normal to the rail and centered at the rail. In addition, the slab shall be designed to support an accidental concentrated load as defined in Section 7.5.4. The effective distribution width (E) of this concentrated load shall be as outlined below.

For deck between supports

$$E = 0.58 \cdot S,$$

but not greater than 3'-0" where S is the span length between centerlines of support.

For cantilever deck

$$\text{Moment: } E = 2.5 + 0.2 \cdot X \text{ [ft.]}$$

$$\text{Diagonal Tension: } E = 4 \cdot t$$

where

X is the distance from load to point of support

t is the thickness of deck

7.7.2.3 System Loads (SL)

Design shall include loads and forces produced by the system-wide elements such as electrification, signalization, and communication equipment. Refer to Chapters 12, 13, and 14 for information concerning the system-wide elements.

7.7.3 Strength Requirement

For bridges supporting LRT only, combine loads according to AASHTO and UDOT Seismic Criteria. For bridges supporting freight, combine loads according to AREMA. Where a bridge supporting freight crosses UDOT right-of-way, combine seismic loads according to AREMA and UDOT Seismic Design Criteria.

The minimum strength required for structural members and their connections supporting the light rail transit loadings shall be computed from the most critical Group listed in Table 7-2.

**Table 7-2: Factors for Load Factor Design
AASHTO Table 3.22.1A Modified**

Beta Factors																
Group	Gamma	D	L+I	DR	CF	E	B	SF	W	WL	NF	LF	RF	RB and S-T	EQ	ICE
I	1.30	BD	1.87	0	1	BE	1	1	0	0	0	0	0	0	0	0
II	1.30	BD	0	0	0	BE	1	1	1	0	0	0	0	0	0	0
II	1.30	BD	1	0	1	BE	1	1	0.3	1	1	1	1	0	0	0
IV	1.30	BD	1	0	1	BE	1	1	0	0	1	0	0	1	0	0
V	1.25	BD	0	0	0	BE	1	1	1	0	0	0	0	1	0	0
VI	1.25	BD	1	0	1	BE	1	1	0.3	1	1	1	1	1	0	0
VII	1.30	BD	0	0	0	BE	1	1	0	0	0	0	1	0	1	0
VIII	1.30	BD	1	0	1	BE	1	1	0	0	0	0	0	0	0	1
IX	1.20	BD	0	0	0	BE	1	1	1	0	0	0	0	0	0	1
X	1.30	BD	1.67	0	0	BE	0	0	0	0	0	0	0	0	0	0
XI	1.30	BD	1	0.85	1	BE	1	1	0	0	0	0	0	0	0	0

For the design of substructure components requiring service load (working stress) analysis, the loads to the substructure components shall be computed from the most critical Group listed in Table 7-3, where the column headings are as listed in Section 7.5.1 and:

LBF = Longitudinal braking and tractive forces

NF = Nosing forces

SL = System loads

RB = Rail break

EQ = Earthquake (seismic)

**Table 7.3: Factors for Service Load Design
AASHTO Table 3.22.1A Modified**

Beta Factors																	
Group	Gamma	L-I			CF	E	B	SF	W	WL	NF	LF	RF	RB and S	EQ	ICE	%
		D	L+I	DR													
I	1.0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	100
IRT	1.0	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0	100
II	1.0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	125
III	1.0	1	1	0	1	1	1	1	0.3	1	1	1	1	0	0	0	125
IV	1.0	1	1	0	1	1	1	1	0	0	1	0	0	1	0	0	125
V	1.0	1	0	0	0	1	1	1	1	0	0	0	0	1	0	0	140
VI	1.0	1	1	0	1	1	1	1	0.3	1	1	1	1	1	0	0	140
VII	1.0	1	0	0	0	1	1	1	0	0	0	0	0	0	1	0	133
VIII	1.0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1	140
IX	1.0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	1	150

% indicates percentage of basic unit stress.

No increase in allowable unit stresses shall be permitted for members or connections carrying wind loads only.

7.7.4 Special Design Considerations

7.7.4.1 Vibration Limitations

To limit potential dynamic interaction between aerial structure girders and light rail transit vehicles, the aerial structure shall be designed so that the unloaded natural frequency of the first mode of vibration of the longitudinal girders is not less than 2.5 cycles per second. Further, no more than one span in a series of three consecutive spans shall have first mode frequency less than 3.0 cycles per second.

7.7.4.2 Track Work

Consideration shall be given to the thermal force interaction between the structural components and the track work system.

7.7.4.3 Fatigue

Consideration shall be given to the effect of change of stress levels caused by passage of light rail transit vehicles over structures. Over the life of the structure, 3 million cycles of maximum stress shall be used in estimating the number of repetitive maximum stress cycles.

7.7.4.4 Uplift

Provision shall be made for adequate attachment of the superstructure to the substructure should any combination of loading listed in Table 7-3 produce uplift at any support. Where DL, E, or any of other loadings tend to reduce the uplift effect, the corresponding load factors shall be taken as 0.9 for DL, 0.75 for E, and 0 for other loadings.

7.7.4.5 Friction

Where applicable, friction shall be considered in the design and incorporated in Groups II and III listed in Table 7-3.

7.7.4.6 End Diaphragms

End diaphragms shall be designed for a jacking force equal to the DL end reaction.

7.7.5 Reinforced and Prestressed Concrete Design

Reinforced and prestressed concrete members for light rail transit aerial structures shall conform to the requirements of Section 7.3.4 except as modified below.

7.7.5.1 Camber and Deflections

As a guide in design, the total long term predicted camber growth less deflection due to full dead load should be limited to 1/2,000 of span length.

7.7.5.2 Live Load Deflections

Girders of simple or continuous spans shall be designed so that the deflections due to live load plus impact shall not exceed 1/1,000 of the span length. The deflection of cantilever arms due to live load plus impact shall be limited to 1/375 of cantilever arm.

7.7.5.3 Longitudinal Tension Stresses in Prestressed Members

Longitudinal tension stresses shall not be permitted under service loadings.

7.7.5.4 Shrinkage and Creep

Stresses and movements resulting from concrete shrinkage and creep shall be considered in the design and included in all load combinations. The shrinkage coefficient shall be assumed to be 0.0002 inches per inch for both prestressed and reinforced concrete.

7.7.5.5 Structure Deformations and Settlements

All structure deformations, including foundation settlement, shall be considered, not only for their effect on structural behavior, but also for their effect on track work. The control of deformations through proper structural design is of paramount importance in obtaining acceptable riding quality for the light rail vehicles.

7.7.5.6 Minimum Concrete Design Strengths and Rebar Spacings

For all underground reinforced cast-in-place structures including box lines and stations, abutments, retaining walls, shafts, cross-passageways, portals, U-sections, spread footings, piles, drilled caissons, and basement walls:

$$f'_c = 4,000 \text{ psi}$$

For all above ground reinforced concrete cast-in-place structures including columns, cap beams, and superstructure for aerial structures and bridges, columns, beams, slabs, foundations, and walls for buildings:

$$f'_c = 4,000 \text{ psi}$$

For post-tensioned prestressed concrete:

$$f'_c = 5,000 \text{ psi}$$

For precast prestressed members:

$$f'_c = 5,000 \text{ psi}$$

For all building foundations, floor slabs, pits, and other miscellaneous foundations at yards and shops and central control building miscellaneous foundations other than those specified, and station platform foundations:

$$f'_c = 3,000 \text{ psi}$$

In certain cases, strengths of concrete other than those specified above might be required. These cases will be as directed by UTA in writing.

To the extent possible, main reinforcing bars shall be spaced at 6", 9", or 12" on center in elements of tunnels, cut-and-cover subway, retaining walls, bridge structures, and stations. Exceptions to this rule include beams, columns, stairways, and thin slabs.

7.7.6 Structural Steel Design

Structural steel and composite steel-concrete flexural members for light rail transit aerial structures shall conform to the requirements of Section 7.3.3.

The requirements governing live load deflections, structure deformations, and settlements as outlined for reinforced and prestressed concrete design shall also apply to structural steel design.

7.7.7 Foundations

Foundations for girder spans up to 150' in length shall not have total settlements greater than 1" nor differential settlements greater than ¼". For spans over 150' in length, the designer shall develop settlement values that meet the approval of UTA. Any proposed deviation from the settlement limits shall be submitted to UTA for prior approval. The designer shall consider the use of approach slabs to mitigate the affects of the differential settlement on the tracks.

7.7.7.1 Drilled Caissons

The design shall keep the maximum bearing pressure at the base of the caisson within the allowable bearing value as determined by the geotechnical consultant. Design should allow for an accidental misplacement of the center of gravity of the substructure of 6" in any direction. The design of drilled piers or drilled caissons shall be in accordance with ACI-336.3R-72, Revised 1985, "Suggested Design and Construction Procedures for Pier Foundations."

7.7.7.2 Lateral Resistance

Consideration shall be given to the ability of piles or drilled caissons to resist lateral loads. When the lateral resistance of the soil surrounding piles is inadequate to counteract the horizontal forces transmitted to the foundation or when increased rigidity of the entire structure is required, battered piles shall be used in a pile foundation. Battered piles shall have a slope not greater than 1 horizontal to 3 vertical. Where battered piles are to be used, consideration shall be given to the possibility of such battered piles encroaching on property outside the right-of-way lines.

The axial loads on piles and caissons shall be determined by static analysis of the moment resistant group, by the method of elastic center, or by any other satisfactory method. Each member, vertical or battered, in a pile or drilled caisson group may be assumed to have horizontal resistance capacity in addition to the horizontal component of the axial load on the battered members, equal to the least of the following values:

- Capacity recommended by the geotechnical consultant
- Capacity of the pile or caisson as a structural member
- 10% of the member's design compressive capacity perpendicular to the strong axis only

Unless a pile or caisson is installed to a sufficient depth in competent material to develop fixity, it shall be assumed to have no capacity to resist lateral loads in bending.

7.8 Soils and Geological Criteria

Earth and water pressures on the earth retaining structures vary considerably with geographical location. Earth pressures and other soil parameters shall be determined by the designer in consultation with the geotechnical consultant. Allowable bearing values for rock or earth in its natural bed shall be based on the above information; otherwise, they shall not exceed the limits given by the local building code, as applicable.

For concrete walls, slabs, and footings less than 48" thick and resting directly against earth, minimum temperature and shrinkage reinforcement shall be 0.15% of the gross concrete area. For members larger than 48" thickness, the temperature and shrinkage reinforcement requirements shall be in accordance with the crack control measures as recommended by ACI-318. For crack control, the maximum bar spacing shall be 18" on centers.

To control shrinkage stresses in concrete slabs and walls and to minimize cracking, a unit length of 50' or less between contraction joints shall be preferred. For units longer than 50' between contraction joints, the construction procedures and requirement for temperature and shrinkage reinforcement shall be in accordance with the crack control measures, as recommended by ACI-318.

7.9 Surface Stations, Shops, and Other Buildings

7.9.1 Surface Stations

Surface stations are defined as stations constructed at grade. Surface stations included in the LRT system shall be designed in accordance with Sections 7.3.3, 7.3.4, and Chapter 8 of these criteria. For applicable loads and forces not included in Section 7.5 of these criteria, the requirements of IBC shall apply.

7.9.2 Buildings

Buildings included in the LRT system shall be designed in accordance with the requirements of Section 7.2, Section 7.5, and Chapter 17 of this manual. Wind loading on the building shall be in accordance with IBC.

7.10 Support of Excavation Structures

Contract drawings and specifications shall cover traffic diversions, mandatory restrictions, and necessary construction staging approved by public authorities and utility companies as applicable. Acceptable locations for construction access ramps, or any other construction facility that affects the work, shall also be indicated. Detailed design of the temporary decking, sheeting, and bracing shall be prepared by the contractor and approved by the designer, based upon criteria and design standards included in the contract drawings and specifications.

It shall be a requirement in the contract documents that the design of support of excavation structures be prepared, checked, and certified by a structural engineer registered in the State of Utah. The review and acceptance of the designs submitted by the contractor shall be made by a structural engineer registered in the State of Utah.

7.11 Elastomeric Bearings

The design of all elastomeric bearings shall consider a minimum shape factor of three, as well as provisions for bearing hardness, bearing replacement and inspection, shear displacement, vertical displacement, rotational capacity, compressive stress, reinforcement strength, stability, and slip.

The material shall be steel laminated 100% virgin chloroprene (neoprene) or natural rubber. Elastomers of nominal 70 or higher durometer shall not be used.

The design of elastomeric bearings and TFE bearing surface shall be in accordance with AASHTO.

The travel of supported span in any elastomeric bearing shall be assumed to be a minimum $\frac{1}{8}$ inch per 10 feet of beam length. The minimum shape factor shall be three for pads, for which a compressive stress/strain diagram has been derived by testing elastomeric bearing of, actual or slightly reduced size. If the diagram has been derived on samples of size reduced by a factor of 2 or more, the minimum shape factor shall be 5. The products offered without compressive stress/strain diagrams or which are claimed to be independent of the shape factor shall not be used.

Every bearing shall be proof tested to 150% of the design load. If bulging patterns imply poor laminate bond, or if there are three separate surface cracks greater than 0.08 inch wide and 0.08 inch deep, the bearing shall be rejected.

Bearings shall have built-in taper when nonparallel load surface would otherwise produce a compressive deflection of $0.06 \cdot T$ under dead load. Such taper shall be limited to $\frac{5}{8}$ inch per foot.

END OF CHAPTER 7.



Utah Transit Authority Light Rail Design Criteria

Chapter 8 Stations

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 8 STATIONS

8.1 General

8.1.1 Scope

This section establishes specific guidelines and standards for the design of stations. The stations will be at-grade (except in special cases), standardized and cost effective in design. Elements discussed in this section include the design of platforms or platform access. Guidelines are provided for the design of bus access, kiss-and-ride and park-and-ride facilities, and for the selection of materials.

The design of the stations shall be standardized. Equipment, shelters, platform features, structural elements, and signage used shall be the same system-wide and compatible with UTA's existing identity. Deviations from standard design elements may be required for specific sites, but must be approved by the UTA Light Rail Project Director before design proceeds.

8.1.2 Codes and Standards

Applicable codes and standards include the most current edition of the following documents:

- International Building Code (IBC)
- Uniform Plumbing Code
- Uniform Mechanical Code
- NFPA, Life and Safety Code
- NFPA, Life Safety for Transit Systems
- Uniform Fire Code
- Uniform Federal Accessibility Standards
- ANSI A 117.1
- Occupational Safety and Health Standards (OSHA) (29FR Part 1910)
- Uniform Electrical Code
- Americans with Disabilities Act (ADA)

Where no provisions are made in the codes for particular features of the design the best architectural practice shall be followed, with the prior approval of UTA.

8.1.3 General Design Parameters

The facilities must be able to serve the needs of patrons efficiently, economically, safely, conveniently, and comfortably. These stations shall also provide for the traditional requirements of public transit systems: identity in neighborhoods or downtown areas as a location for public transit, shelter from severe weather, and cover and/or screening from average weather conditions.

In designing the facilities, the anticipated growth and long-term life of the system shall be considered. Function and life cycle consideration are important, as are aesthetics and the overall quality and character of the facilities. Station design shall be compatible in design with the immediate vicinity and reflective of the regional context of the Salt Lake Valley.

Stations shall be standardized to provide a consistently understandable experience for transit users. Standard graphic information systems are especially important. Consistency reduces inventories for replacement parts and equipment for maintenance and costs. UTA has adopted standard graphic criteria as contained in Appendix I.

In all segments, it is essential that great care be taken in coordinating final design with UTA, the affected communities and neighborhoods, adjacent property owners or developers, public agencies, or community groups having jurisdiction over or significant interest in the human environment and design of facilities at stations and along routes. Coordination with the development plans and master plans of local communities and neighborhoods is essential to blending the transit system into the urban fabric of the Salt Lake Valley, and in assuring that UTA needs and community needs are met.

8.2 Platform Geometrics

8.2.1 Configuration

Platforms will be low-level center platform type. Disabled persons will be able to board the LRV by utilizing the mini-high block at the head of the platform, when low-floor vehicles are not used.

The platform length available for boarding and alighting shall be for a 4-car train. The mini-high block ramp length may add to the total platform length.

Typical center platform width is nominally 17'-10" and shall consider location, configuration, current ADAAG accessibility guidelines, and clear space around station amenities and columns. Where applicable, typical side platform width is nominally 14'. The actual width of the low platform shall extend to the static outline of the light rail vehicles to eliminate unsafe voids between the platform and the lowest steps of the vehicle. The extra gap caused by maintaining freight vehicle clearances will be bridged at the mini-high block. Figures 3-6a and 3-6b illustrate the location of the platform with respect to the tracks.

8.2.2 Platform Height and Offsets

- The platform height shall be 8 inches above the top of rail; the offset from the centerline of track shall be as listed in Chapter 3.
- All platforms shall have a drainage cross slope to the trackside of 1–2%.

8.2.3 Platform Surface and Edge Treatment

The surface of all platforms shall be non-skid and of long-wearing weather resistant materials. The tactile tile near the platform edge shall be yellow, high-strength concrete tiles. Tiles shall be designed to accept the bridge plate of a light rail low-floor vehicle. This strip shall meet ADA requirements, currently 24 inches wide from the car clearance envelope on tangent or curved platforms. The warning strip shall not impede the passage of a wheelchair but shall be sufficiently rough or different to be felt by sight-impaired patrons.

8.2.4 Rail Vehicle Clearance and Description

Light rail vehicles produced by numerous manufacturers and in operation at various transit properties in North America will meet the requirements of UTA. Refer to Chapter 11 for composite LRV dimensions.

8.3 General Station Requirements

8.3.1 Weather Protection

Generally, there shall be canopies over portions of each platform including the ticket vending area. The canopies shall be supported by columns centered on the platform width. They shall be designed to allow snow and ice to melt without dropping on the patrons. The canopies will be of uniform design and size and shall allow for ease of expansion. The canopies shall be composed of durable components currently in use in the Wasatch Front Region, and economical to repair or replace.

8.3.2 Fare Vending Equipment

Fare-vending equipment will be installed at all stations. 120 Vac, single-phase power will be provided for all equipment requiring electric power. Spare conduit will be provided to accommodate future additions and changes. The equipment shall be located near main entry points or centered on the platform to minimize the length of travel for patrons. Refer to Chapter 15 for detailed information. Provisions shall be made for two additional fare vending machines per station in the future.

8.3.3 Patron Amenities

Elements associated with platforms may be provided by UTA or an outside establishment.

- Public Telephones—Space shall be provided on or adjacent to all platforms for the installation of public telephones, as agreed by UTA and the telephone companies.
- Seating—Benches capable of seating 6–8 persons each shall be provided at one or more location on the platform. Seating shall not allow lying down, nor sitting on top of the back rest.
- Bicycle Storage—Space for bicycle racks and/or storage lockers may be provided at stations, outside of platform areas.
- Newspaper Racks—. Space shall be provided at the stations or adjacent to bus and/or park-and-ride facilities for coin-operated newspaper vending machines as far as zoning permits this use and/or adjacent sidewalks subject to local jurisdictional requirements.
- Trash Receptacles—Shall be provided at all stations and integrated into the “installation.” Trash receptacles shall be sensitive to Homeland Security Safety Standards.
- Communications—See Chapter 15 of this criteria for description of the communications system. A minimum of two conduits will be placed along the length of the station for each station. These conduits will be used for a future message/communications systems. No antenna shall be located on station platforms.
- 120VAC receptacles will be provided for use by vendors outside the platform areas.

8.3.4 Signing

The basic objectives of the system signing is to guide persons to and through the system in the most efficient, safe, and user friendly manner using simple, strong, and precise style, organized in systematic and sensible layouts. Sign communication shall be further enhanced by proper placement of signs and careful determination of sign dimensions and quantities.

Signs shall be standard throughout the LRT system. Each station will have a system map and schedule. The signing is to emphasize the LRT system identity and be consistent with existing UTA signage. They shall be designed according to ADA standards.

8.3.5 Advertising

The station shelter and other elements may be able to accommodate advertising. The application may vary by neighborhood and local ordinances. Advertising displays shall conform to a system-wide standard of frames and finishes subject to local jurisdictions.

NOTE: *There are no provisions for advertising in the UTA TRAX system designs.*

8.3.6 Maintenance Space and Procedures

All station maintenance will be performed by UTA personnel during revenue hours. Major pieces of maintenance and repair equipment will be moved to the station from a central facility where equipment, supplies, and materials are stored. 120 V receptacles will be provided for use during maintenance.

8.3.7 Communication and Power Conduits

Each center platform will contain two 2" conduits for UTA communication wire and fiber on the south or east side of the platform. Additionally, each center platform will contain two additional conduits for 2" conduits for power on the north or west side of the platform. These conduits will run from the power control cabinet and along the entire length of the platform, terminating at a pull box on each end of the run. Snow melt sensor needs will be in addition to these conduit needs. Appropriately spaced pull boxes will be installed. On side platforms, the communication conduits will be located on the inside (trackside) of the platform and the power/sensor conduits will be located on the outside of the platforms. Conduits in the platform area will be concrete encased. Pull boxes should be located outside of primary walk paths.

Lateral conduits will be provided from the communications and power conduits to each of the following locations: ticket vending machines, phones, canopies (for lights, public address, and passenger information signs), stand-alone message signs, light poles, and kiosks.

8.4 Circulation Elements

The stations in the system are functional spaces for patron circulation, waiting, and access to the transit vehicle. Therefore, the stations shall be designed as efficient conduits to accommodate peak demands without undue delay.

8.4.1 Pedestrian Patterns

The criteria listed in this section are minimum guidelines relevant to pedestrian circulation and they should not supplant the logic of a better functional solution, should it develop.

There are three distinct groups that must be considered in the design of pedestrian circulation:

- Regular users
- Infrequent users
- Disabled users

The three groups move through the system in varying ways:

- Regular users move quickly with a minimum of guidance
- Infrequent users move easily with great reliance on signs for guidance
- Disabled users move slowly with the guidance required depending on the frequency of use and the degree of the disability

The following general principles shall be employed to accommodate these varying demands:

- Stations should be designed to directly and safely accommodate anticipated pedestrian movements. The direction of circulation elements shall be as obvious as possible to aid recognition.
- Queuing space is desirable ahead of every barrier, and in front of ticket vending machine (TVM) installations.
- No obstructions shall be permitted within the main pedestrian flow. This area shall be defined as an approximate 6-foot clear strip along the track side of the platform.
- Shelter areas shall have sufficient transparency to give adequate visual surveillance of these spaces for user safety and to discourage vandalism.
- Pedestrian access from bus, kiss-and-ride, and park-and-ride areas must be clear and as simple as possible with no visible barriers.

8.4.2 Elements of Vertical Circulation

All vertical circulation elements shall be designed in accordance with ADA requirements. Ramps shall be provided at all changes of grade and be available to any rider needing or wishing to utilize them. Grades within the station and pedestrian area of the park-and-ride lot should not exceed 5%. Ideal grades for the facility are 1.5 to 3%.

8.4.2.1 Ramps and Mini-High Blocks

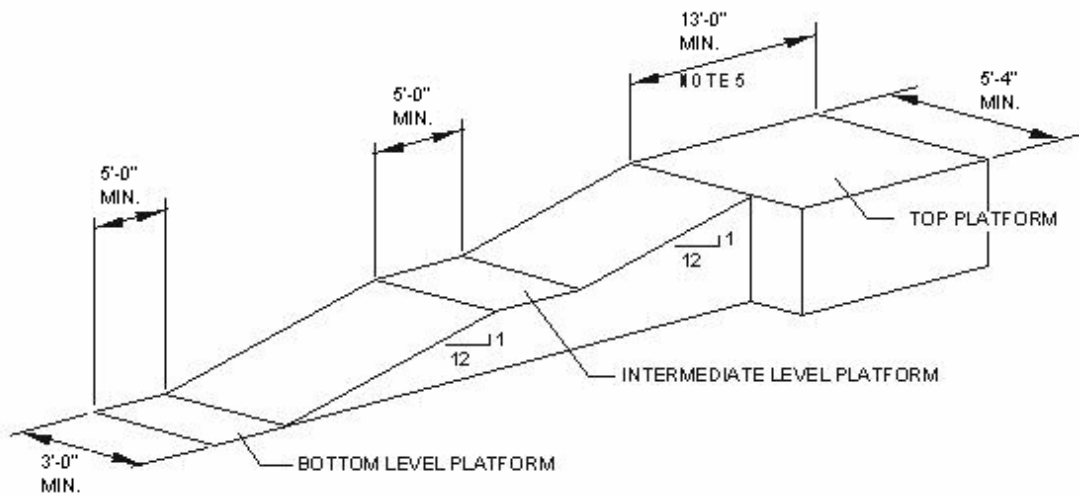
A path of travel with a slope greater than 1:20 shall be considered a ramp. Ramps shall be provided to the platforms as required for topographic changes.

Generally the ramps on this project will be used to travel from the platform to the mini-high block platform or to transition small elevation differences, such as from the curb to the parking lot. The standard drawings of each local jurisdiction should be consulted.

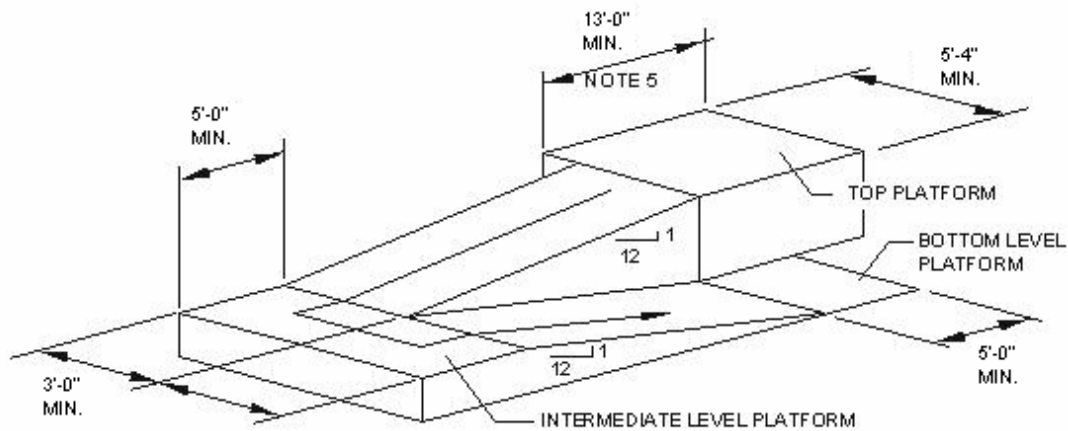
For the mini-high block access ramps and any ramp where the vertical rise between landings exceeds 6 inches and/or the slope of ramp is between 1:12 and 1:20, handrails shall be provided on each side of any ramp. The handrails shall be continuous, placed between 30 and 34 inches above the top and bottom of the ramp, with returned ends as per code. The surface of ramps shall be slip-resistant. The minimum dimensions for the mini-high block ramp is shown in Figure 8-3.

Mini-high block platforms shall be covered by a roof, maintaining appropriate clearances, and have a windscreen or at least two adjacent sides.

Figure 8-3: High Block Minimum Dimensions



STRAIGHT RAMP RUN



RAMP WITH INTERMEDIATE SWITCH-BACK PLATFORM

NOTES:

1. total horizontal distance of ramp will vary.
2. All ramps must meet handrail, curb and tactile strip requirements.
3. All details must meet requirements for ADA current edition, including 3'0" dimension satisfying clear distance requirements.
4. This graphic must meet ADA Requirements, current edition.
5. Opening shall be 7'0".
6. Designers shall use 1:13 or flatter for construction tolerances, 1:12 is maximum allowable per ADA.

8.4.2.2 Stairs

The minimum width of stairs for public use shall be 48 inches. The minimum length of landing for straight-line stairs shall be 54 inches.

8.5 Lighting

The station lighting shall include all lighting required to light the platform, mini-high platforms, bus loading area, kiss-and-ride area, park-and-ride lots, and pedestrian walkways associated with the station.

Lighting design may be subject to local jurisdictional design criteria.

Artificial lighting shall be provided for safety in all open station site areas with due consideration for adjacent land uses. The average maintained footcandle values are indicated in Table 8-1. The average footcandles listed may require reduction at station locations in low-density residential areas. Light fixtures shall be provided with a cutoff feature to eliminate candle power at high angles.

Artificial light sources to obtain the required footcandle levels shall be no higher than 15 feet in stations and 30 feet in parking lots. Light fixture size, pole height, and number of poles shall be selected to optimize footcandle and aesthetic design criteria. Design consideration should be given to place lighting on separate circuits in order to phase lighting levels and provide reliability.

Pole foundations shall extend approximately 24 inches above parking lot grade to reduce pole damage. However, pole locations within the lot area shall be selected to permit future re-configuration of stall and aisle layout to accommodate vehicle size. Pole locations should be placed in landscape islands with curbing whenever possible to add extra protection from vehicle damage.

Lighting control shall be accomplished by the use of photocell units and contactors. This will provide operational cost savings.

Table 8-1: Illumination Design Level

Mode Change Location	Average Maintained Footcandles at Ground Level
Station Platforms	3–5
Park-and-Ride Areas	Local jurisdictional criteria
Entrance and Exit Roads	Local jurisdictional criteria
Kiss-and-Ride Areas	Local jurisdictional criteria
Pedestrian Walkways	Local jurisdictional criteria
Bus Loading Zones	Local jurisdictional criteria
Note: Uniformity for all locations should be vertical/horizontal = 0.75–1.25/1, where vertical is footcandles up to 8'-0", and horizontal is footcandles at ground level.	

8.6 General Station Site Design Guidelines

8.6.1 Vehicular Entrances and Exits to Station Site Facilities

The design of entrances for motor vehicles shall take into consideration adjacent land uses by avoiding large unplanted, paved areas or dimensions that are out of scale compared to adjacent streets and structures. Curb cuts shall be minimized, while fulfilling the following requirements:

- Access is preferred from minor arterials and collectors.

- Access roadways to station sites should be designed to contain sufficient traffic storage capacity to meet expected transit patronage at peak times and to prevent backing up into public streets.
- Conflicts should be avoided between access roadways and large pedestrian movements.
- Access to a station site with more than 1,000 spaces should be from more than one street since the availability of several feeder routes is desirable.
- Access management shall be applied as much as possible. Access coordination with local jurisdictions and Utah Department of Transportation shall look to anticipate future road relocations or changes that can be anticipated within a reasonable time.

8.6.2 Kiss-and-Ride Facilities

Kiss-and-ride drop-off and short-term parking facilities in the station area shall:

- Allow easy movement to locations near the station platforms.
- Be separated from the long-term parking area.
- Have stall widths of 10 feet (min.) to ease quick vehicle movements in and out.

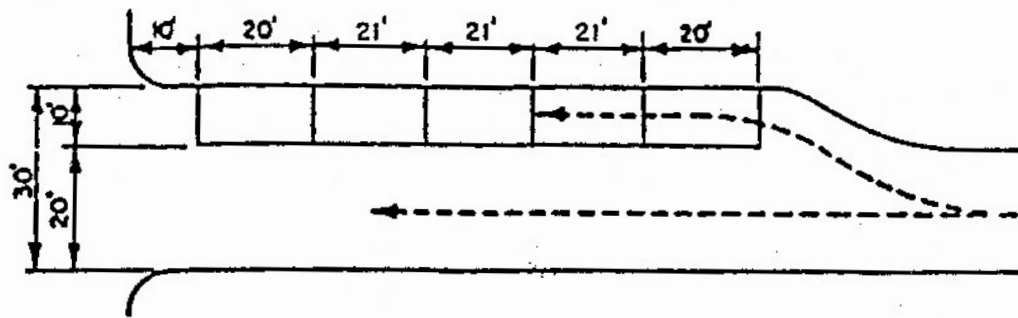
Parking lot design and landscaping (see Chapter 9) may be subject to local jurisdictional requirements.

Preferred parking arrangements for kiss-and-ride areas are in the following order of preference:

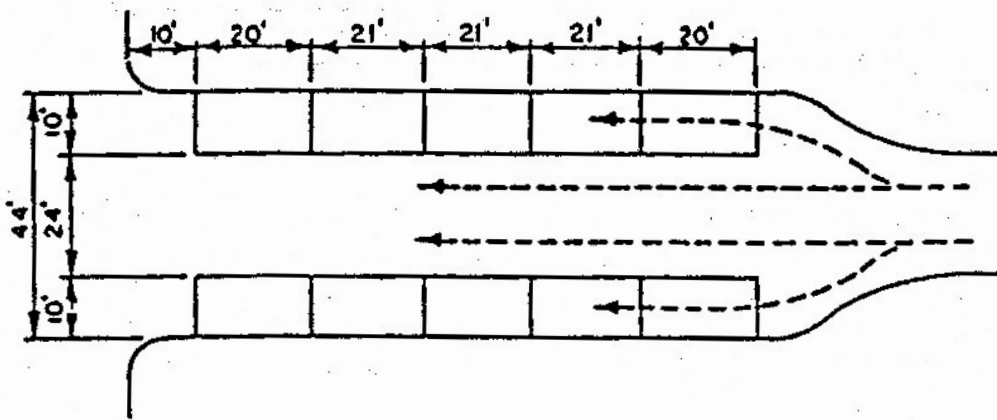
- Parallel to curb (see Figure 8-4)
- 45 degrees to the aisle (see Figure 8-5)
- 60 degrees to the aisle (see Figure 8-6)

Figures 8-4 through 8-6 show recommended stall and aisle widths for the kiss-and ride area.

Figure 8-4: Kiss-and-Ride Parking Arrangement Stall Layout Parallel to Curb



KISS-AND-RIDE FACILITY WITH ONE DROP-OFF LANE



KISS-AND-RIDE FACILITY WITH TWO DROP-OFF LANES

Figure 8-5: Kiss-and-Ride Parking Arrangement Stall Layout 45°

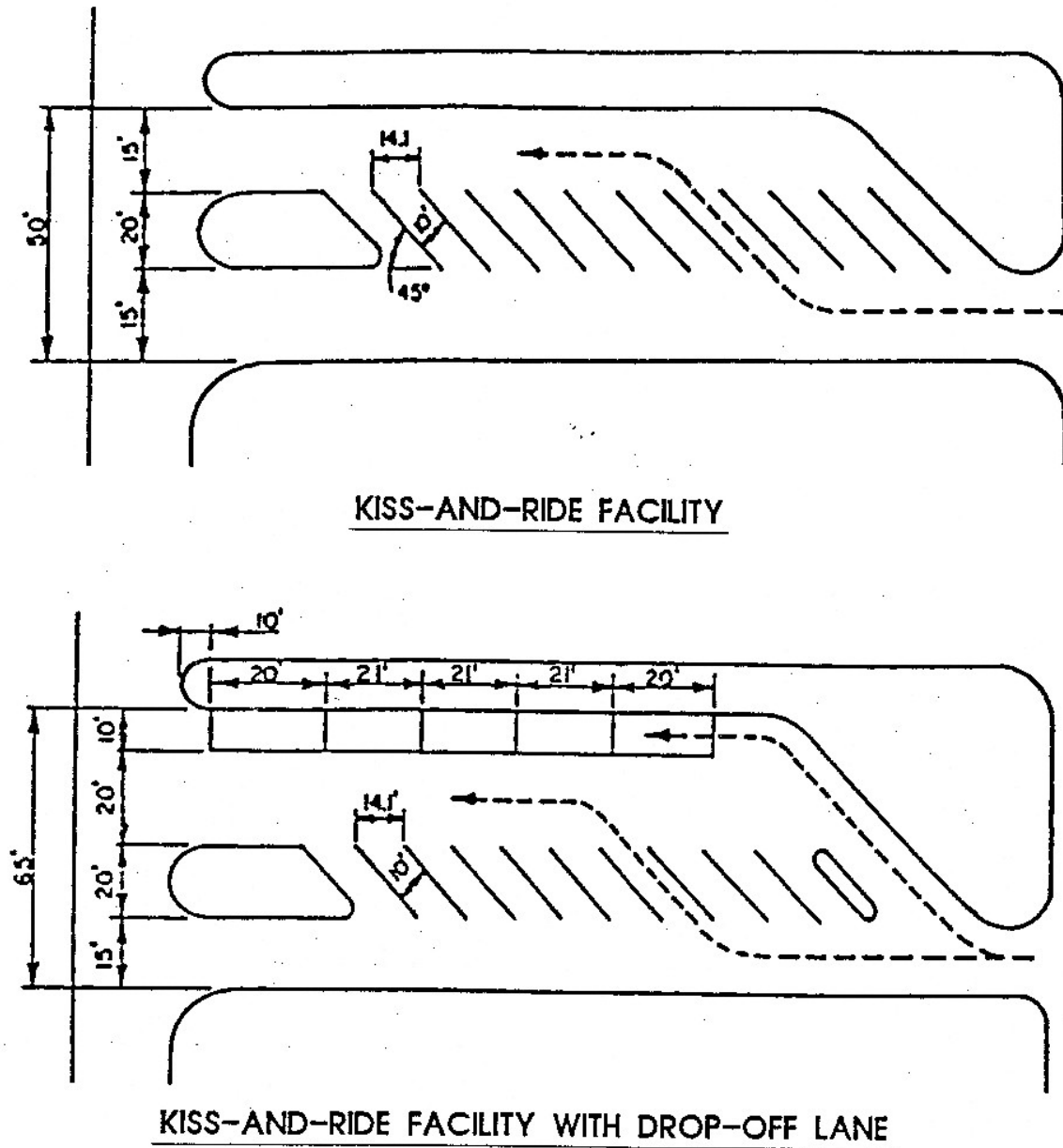
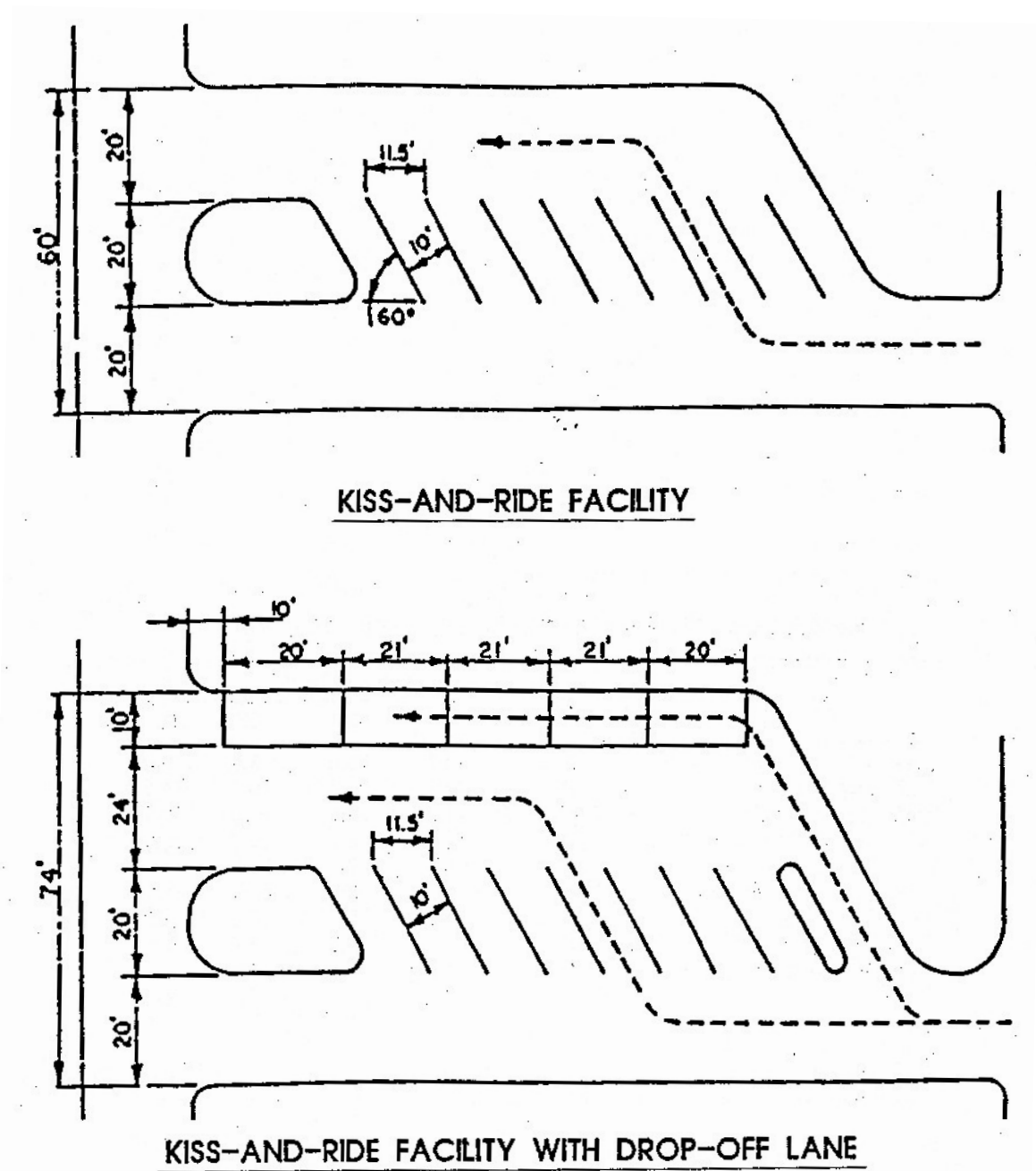


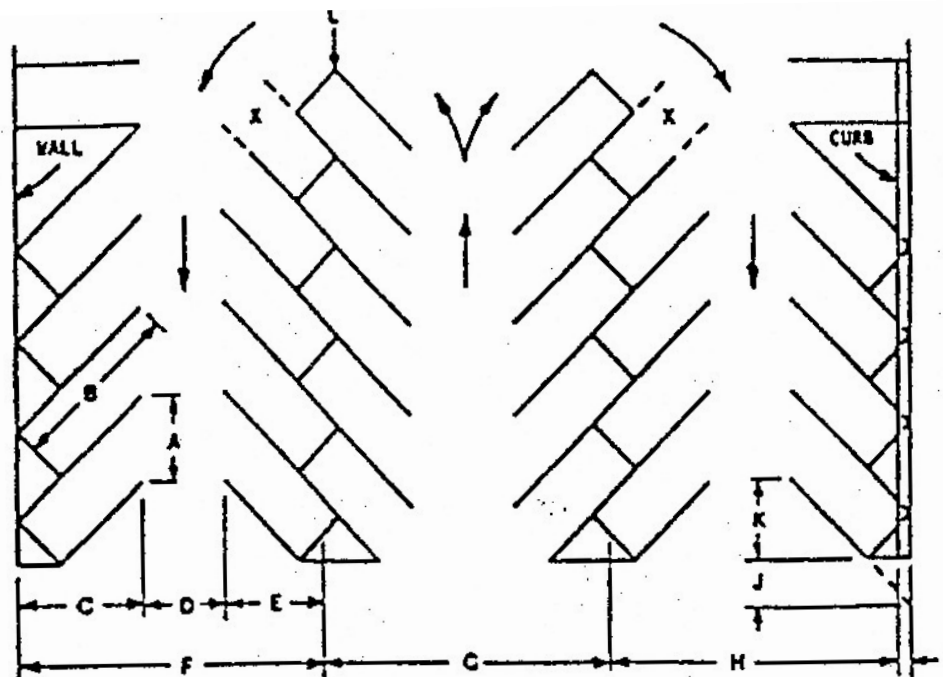
Figure 8-6: Kiss-and-Ride Parking Arrangement Stall Layout 60°



8.6.3 Park-and-Ride Facilities

The park-and-ride areas shall be designed to optimize the site area allocated by using the concepts and dimensions shown on Figure 8-7, and outlined in the following sections. Design shall conform to local jurisdiction requirements. Refer to Chapter 5 of Light Rail Design Criteria to identify civil element criteria for the site work of the facility. Site work shall follow American Public Works Association or Utah Transit Authority standards and specifications wherever possible.

Figure 8-7: Parking Layout—9-Foot Stalls



X = Stall not accessible in certain layouts

Parking Layout Dimensions (In feet) for 9-ft. Stalls at Various Angles

Dimension (feet)	On Diagram	Angle			
		45°	60°	75°	90°
Stall width, parallel to aisle	A	12.7	10.4	9.3	9.0
Stall length of line	B	25.0	22.0	20.0	18.5
Stall depth of wall	C	17.5	19.0	19.5	18.5
Aisle width between stall lines	D	12.0	16.0	23.0	26.0
Stall depth, interlock	E	15.3	17.5	18.8	18.5
Module, wall to interlock	F	44.8	52.5	61.3	63.0
Module, interlocking	G	42.6	51.0	61.0	63.0
Module, interlock to curb face	H	42.8	50.2	58.8	60.5
Bumper overhang (typical)	I	2.0	2.3	2.5	2.5
Offset	J	6.3	2.7	0.5	0.0
Setback	K	11.0	8.3	5.0	0.0
Cross aisle, one-way	L	14.0	14.0	14.0	14.0
Cross aisle, two-way	—	24.0	24.0	24.0	24.0

STALL LAYOUT ELEMENTS

Standard, 9 x 18

8.6.3.1 Motorcycle Parking

Motorcycle parking stalls may be added in triangles and corners set off by the park-and-ride layout which are readily accessible to the station.

8.6.3.2 Bicycle Racks

Bicycle storage may be provided, as directed by UTA (refer to Section 8.3.3). Racks shall conform to the requirements listed below:

- Located so as to be readily visible
- Located to cause minimum interference with other station activities
- Provide a secure stanchion that allows bicycles to be locked

Wherever possible, bicycle racks shall be installed parallel to the track between it and any directly adjacent area of pedestrian access. This shall encourage patrons to walk to either side of the bicycle racks to reach the designated track crossings at the platform ends.

8.6.3.3 Borders of Parking Areas

Parking lots should be designed to avoid the use of earth retaining structures, and to keep all work within UTA's right-of-way lines. Curbs should be provided at all parking lot edges. Borders should be wide enough for landscaping and planting. Requirements for storm water management shall be considered in the design of the parking lot and border.

8.6.3.4 Pedestrian Access

Pedestrian circulation shall provide direct and convenient approaches to station platforms from off the site and from each of the individual sections of the lot. Parking aisle orientation shall be planned to consider pedestrian directness, lot capacity, and pedestrian safety. Pedestrian movements within the park-and-ride area will normally occur within the driving aisles. However, pedestrian walkways may be provided to minimize vehicular interference, to reduce the number of points where pedestrians cross the aisles, or to shorten irregular routes through successive aisles by a considerable distance. Pedestrian access to station platforms that cross train tracks shall conform to ADA requirements including providing a tactile warning surface. Storm water management shall conform to local jurisdiction requirements.

8.6.3.5 Operator Restrooms

At terminus stations and others where needed, operator restrooms shall be incorporated into the station site design. They shall be located near the platform so as to be easily reached from the cab of a parked train, and accessible with a key only. Motion sensor lights shall be considered in the design of these facilities to reduce operational costs.

8.6.3.6 Water Connections

Provide water connections or hose bibs so any location on the platform can be reached by a 100-foot-long hose. Consider water connection applications for winter use.

8.6.4 Security Infrastructure

Add conduit infrastructure for future security cameras and emergency telephones in proposed park-and-ride lots. At a minimum, place four 1½" conduits from station pull box or power control cabinet to strategic poles in the park-and-ride lot for future installation of wires. Coordinate details with UTA security, IS, and Capital Development personnel.

8.6.5 Heated Platforms

Technology shall be considered for a snow melt system on platforms. Proven technology can be added to an LRT project at the discretion of UTA Project Director and Facilities Maintenance Manager. Funding would derive from Facilities Maintenance budget.

8.7 General Materials and Finishes Guidelines

The following basic requirements and criteria have been established for the finish of public areas within the system. While convenience, comfort, and attractiveness shall be considered in the selection and application of these finishes, safety, durability, and economy are essential attributes.

8.7.1 Safety

- Flammability and smoke generation hazard from fire shall be reduced by using finish materials with minimum burning rates, smoke generation, and toxicity characteristics consistent with Code requirements as noted in IBC and NFPA 101, Life Safety Code, 1988 (or most current edition).
- Hazard from dislodgment due to temperature change, vibration, wind, seismic forces, aging, or other causes, shall be reduced by using proper fasteners and adequate bond strength.
- Pedestrian safety shall be increased and the presence of the disabled shall be recognized by using floor materials with non-slip qualities. Stairways, platform edge strips, ramps, and areas around equipment shall have high non-slip properties.
- Edging and flooring shall be electrically insulated. No grounded metallic surface shall be installed within 5'-0" of the edge of the platform adjacent to trains.
- Electrical protection and conductors shall be sized in accordance with NFPA 70 (NEC).
- All current-carrying enclosures shall be effectively grounded.

8.7.2 Ease of Maintenance

8.7.2.1 Cleaning

Facilitate cleaning and reduce cleaning costs by the use of materials that do not soil or stain easily, which have surfaces that are easy to clean in a single operation using standard equipment and cleaning agents, and on which minor soiling is not apparent.

8.7.2.2 Repair or Replacement

To reduce inventory and maintenance costs, materials shall be used that can be easily repaired or replaced without undue cost or interference with the operation of the LRT system. For example, hose bibs, electrical outlets, lighting fixtures and lamps, glass or plastic lights, etc., shall be standardized with commonly available sizes and finishes to ease inventory stocking or direct purchase.

8.7.3 Resistance to Vandalism

Materials and details that do not encourage vandalism and that are difficult to deface, damage, or remove shall be used.

All surfaces exposed to the public shall be finished in such a manner that the results of casual vandalism can be readily removed with common maintenance techniques.

8.7.4 List of Finish Materials

This list shall apply to all areas of public use. The use of items listed as “acceptable” is subject to location and environmental considerations. All materials shall conform to the requirements of ADA.

8.7.4.1 Acceptable Paving Materials

- Non-slip or other textured-finish concrete
- Stamped-pattern concrete
- Bituminous paving (in carefully defined areas or where required for consistency with adjacent paving)
- Quarry tiles (non-slip)
- Paver brick (dense hard)
- Selected artificial stone materials
- Precast pavers
- Natural stone pavers

Other paving materials may be acceptable, subject to UTA and local jurisdictional approval.

8.7.4.2 Unacceptable Paving Materials

- Synthetic resin surfacing
- Standard cement terrazzo
- Bituminous surfacing, except as noted above
- Marble
- Wood products

8.7.4.3 Acceptable Metallic Surfaces and Finishes

- Stainless steel (areas of high pedestrian use)
- Black wrought iron
- Unfinished galvanized steel (where there is no contact with pedestrian touch)
- Factory applied hard-baked enamel
- Color anodized aluminum (where there is a low degree of pedestrian touch)
- Pressure-treated heavy timber and glue-laminated wood (min. 3" dimension)

8.7.4.4 Unacceptable Metallic Surface Finishes

Jobsite-painted metals are unacceptable metallic surface finishes.

8.7.4.5 Acceptable Canopy Materials

- Steel with factory finished baked enamel
- Safety glass
- Silicone or Teflon coated fiberglass (where out of reach of vandals)

- Painted enamel
- Anodized aluminum

8.7.4.6 Unacceptable Canopy Materials

- Ordinary glass
- Uncoated fabric
- Ordinary plastics
- Combustible materials

END OF CHAPTER 8.



Utah Transit Authority Light Rail Design Criteria

Chapter 9 Landscaping

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 9 LANDSCAPING

9.1 General

This section provides objectives and design parameters for the landscaping of LRT facilities. These include stations, park-and-ride lots, kiss-and-ride areas, and the yard and shop site. Designs shall be consistent with the guidance provided in these criteria. Exceptions may be necessary in some specific cases, and recommendations or discussion of deviations are encouraged where this might result in improved design and less cost. Deviations from the guidelines provided in the design criteria manual documents must be approved in writing by the UTA Light Rail Project Director.

9.2 Objectives

1. Provide a landscape design responsive to and compatible with intended LRT operations, station architecture, lighting, and the construction and operational budget.
2. Provide a safe, secure, and comfortable environment throughout the transit system, particularly at the stations.
3. Assist in controlling access to the system by reinforcing designated pedestrian and vehicular circulation system movements and creating barriers as required.
4. Achieve landscape design that is compatible with local climatic conditions and conserves water and other resources. The long-term goal of the landscape design is to be sustainable without supplemental water. In order to establish such a landscape, a temporary irrigation system should be installed for a period of two to three years, depending on conditions. Following establishment of the landscape, the irrigation system may be used periodically to mitigate extreme conditions.
 - Plants shall be drought tolerant and native or adapted species which provide color and textural interest to the transit environment, and which create a pleasant pedestrian-oriented facility.
 - Plants shall be grouped according to their water requirements and the temporary irrigation system shall be zoned accordingly. The principle of a water conserving landscape shall be employed.
 - Mulch shall be provided in all shrubs and ground cover beds and other landscape areas not planted in lawn.
5. Achieve a landscape design that is compatible with the regional aesthetic character and with the character of existing neighborhoods adjacent to the LRT line.
6. Create a permanent landscape that requires minimal maintenance and non-interference with LRT power lines. Trees and shrubs with fruits or seeds which can stain pavements or create hazards, plants which are prickly or poisonous, and shallow rooted trees which can damage pavements shall not be used.
7. Provide a landscape irrigation system which requires little maintenance, and is automatic, vandal resistant, and water conserving. The system shall provide freeze-protected hose bibs which can be used to clean pavement surfaces and plant materials.

8. Establish visual identity through consistent use of a few basic construction elements and plant materials, where required, while maintaining visual interest and compatibility with adjacent areas through the use of other materials that vary from site to site.
9. Establish visual screening where required by the environmental process, through the use of walls, fences and planting.
10. Protect existing views and vistas.
11. Protect existing plant materials, particularly mature trees, and to replace such material which must be removed during construction. Minimum sizes for new plant materials shall be as follows: 2½" caliper deciduous trees, 6' evergreen tree, 5 gallon shrubs, 1 gallon ground covers and perennials.
12. Coordinate grading required for landscape design with overall site grading requirements.
13. Consider trees on platform areas not within the railroad rights-of-way. Trees may be placed near station areas in railroad rights-of-way, but not on corridor platforms for maximizing survival rate.

9.3 Recommended Plant List—Low Water Use

The plants contained in the following lists are either native or adapted species which are known to survive and thrive with minimal water. This should not be considered a comprehensive or exclusive list as there are other species and varieties which may also be appropriate. It will be critical that the plants receive adequate moisture with regular irrigation during their two-year establishment period. Following the establishment period, supplemental watering can be gradually reduced until the plants are adapted. The irrigation system should remain intact for periodic watering during drought periods and to maintain the plants in a healthy condition with minimal water.

Many of the species listed below are available in several varieties. Water needs should be checked carefully prior to specifying. An asterisk (*) adjacent to the botanical name indicates a moderate to high tolerance to saline soil conditions.

9.3.1 Trees

<i>Botanical Name</i>	<i>Common Name</i>
Acer platanoides	Columnare Maple
Acer glabrum	Rocky Mountain Maple
Acer grandidentatum	Bigtooth Maple
Catalpa speciosa	Western Catalpa
Celtis occidentalis	Common Hackberry
Crataegus sp.	Hawthorns
Juniperus osteosperma	Utah Juniper
Juniperus scopulorum	Rocky Mountain Juniper
Juniperus sp.	Junipers
Gleditsia triacanthos enermis*	Thornless Honeylocust
Koelreuteria paniculata	Goldenrain Tree
Maackia Amurensis	Amur Maackia
Malus sp.	Crabapples
Parrotia Persica	Persian Ironwood
Robinia 'Idaho'*	Idaho Locust
	*Purple Robe Locust
	Black Locust

9.3.2 Vines and Ground Covers

<i>Botanical Name</i>	<i>Common Name</i>
Artemesia schmitiana	Silvermound
Cerastium tomentosum	Snow in Summer
Cotoneaster dameri	Rock Cotoneaster
Juniperus sp.*	Junipers
Lonicera japonica halliana	Hall's Honeysuckle
Mahonia repens	Creeping Mahonia
Parthenocissus quinquefolia	Virginia Creeper
Parthenocissus tricuspidata	Boston Ivy
Sedum sp.	Stonecrop
Thymus sp.	Thyme
Vinca minor	Dwarf Periwinkle
Lysimachia nummularia	Creeping Jenny

9.3.3 Flowers and Forbs

<i>Botanical Name</i>	<i>Common Name</i>
Achillea millefolium*	Yarrow
Coreopsis sp.	Coresopsis
Echinacea sp.	Coneflower
Eriogonum umbellatum	Sulfur Flower
Gaillardia aristata	Blanket Flower
Geranium viscosissimum	Wild Geranium
Hemerocallis sp. sissimum	Daylily
Iris sp.	Iris
Lavandula sp.	Lavender
Linaria nevadensis	Elfiin Delight Flax
Oenothera sp.	Primrose
Penstemon sp.*	Penstemon
Sphaeralcea grossulariefolia	Gooseberry Leaf
Globemallow	

9.3.4 Ornamental Grasses

<i>Botanical Name</i>	<i>Common Name</i>
Agropyron intermedium	Intermediate Wheatgrass
Agropyron sibericum	Siberian Wheatgrass
Agropyron trichophorum	Pubescent Wheatgrass
Bouteloua gracillis	Blue grama
Buchloe dactyloides	Buffalograss
Helictotrichon sempervirens	Blue Oat Grass
Festuca sp.	Fescue
Miscanthis sp.	Maidenhair Grass
Oryzopsis hymenoides*	Indian Rice Grass
Sporobulus airoides*	Alkali Sacaton
Stipa sp.*	Needlegrass

END OF CHAPTER 9.



Utah Transit Authority Light Rail Design Criteria

Chapter 10 Traffic Control and LRT Signal Priority System

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
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CHAPTER 10 TRAFFIC CONTROL AND LRT SIGNAL PRIORITY SYSTEM

10.1 Introduction

This section establishes the basic traffic engineering criteria to be used in the design of light rail transit (LRT) Signal Priority System. It includes criteria for the design of traffic signal systems as related to the LRT priority system, LRT detection system, traffic signal timing plans, LRT priority system testing, traffic signal hardware requirements as related to the LRT priority system, intersection and mid-block signing, and pavement markings.

10.2 Applicable Standards

Traffic control signs and markings shall be in accordance with the practices of the local jurisdictions and with the State of Utah Department of Transportation Standard Plans and Specifications. In the cases where there are no standards, the *Manual of Uniform Traffic Control Devices*¹ (MUTCD) shall be followed. Traffic signals shall be in accordance with the Traffic Signal Systems Specification.

Materials used in the installation and/or modification of signs, pavement markings, and traffic signal systems shall conform to the latest material specifications as stated in the Standard Specifications for Construction and Materials, and State of Utah Department of Transportation, appropriate addenda. The National Electrical Code specifications will supplement where required, as stated in the Traffic Signal Systems Specification.

10.3 General Operations

Where LRT vehicles (LRV) will be operating on existing streets mixed with general traffic, they shall travel no faster than the roadway speed limit and per MUTCD at Highway–LRT at-grade intersections. The dynamic outline of the cars shall be delineated or physically separated from general traffic operating on the same street. Delineation shall be provided by a textured strip of pavement placed so that the edge of the delineation strip nearest the LRT tracks will be outside the dynamic outline of the LRV. Traffic signals, pedestrian signals and any special LRT signs and signals required shall be installed in accordance with the latest edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) and applicable state and local agency standards, as stated in the Traffic Signal Systems Specification.

For the on-street operations, LRT signals shall be provided, in addition to, the traffic signals controlling motorists. These LRT signals shall be distinct from traffic signal equipment in both appearance and indication. LRT signals shall be placed at all signalized intersections, as well as other locations (i.e. mid-block) as required. Existing traffic and pedestrian signal installations shall be retained where indicated on the plans, and the existing interconnect system shall be utilized. LRT signals, existing traffic and pedestrian signal installation shall conform to the requirements stated in the Traffic Signal Systems Specification.

All signalization design shall be coordinated with local jurisdictions and UDOT. The goal of the design is to provide light rail vehicle progression while maintaining due regard for cross-street signal progression. Signal priority is required for the LRT street-running alignments. Signal design shall use a separate phase for LRT movements, where appropriate, to avoid conflicts. It shall be the contractors responsibility to determine the phasing at each intersection that the LRVs pass through. Such a design process shall include a determination of the appropriate phasing for the LRV (whether the LRV requires a phase of its own, or whether it can run concurrently with parallel traffic). Such an analysis shall be based on

operational as well as safety considerations, and the results shall be approved by the owning agencies. The owning agencies shall approve all operational parameters at the conceptual stage.

In a dedicated rail corridor, LRT crossings of existing streets shall be protected by railroad-type crossing gates, flashers, and other appropriate warning devices. Median islands shall be installed wherever possible to discourage vehicles from driving around the gates. Non-mountable curb is acceptable. The adjacent traffic signal controllers shall operate in either an isolated mode (free) or in a coordinated mode as determined to be appropriate at each grade crossing. Adjacent traffic signals on cross streets shall be coordinated as deemed appropriate by traffic engineering analysis and consultation with local officials. Section 13.5.4 may be referred to for further details relating to LRT grade crossing signalization.

10.4 Design Guidelines

10.4.1 General

- Controllers compatible with existing hardware and software, appropriate to each jurisdiction, shall be utilized.
- Where there are existing cables interconnecting traffic signals, they shall be utilized. New traffic signals are required to be integrated into the existing coordination system.
- Designs shall be coordinated with the agency and utilities controlling the intersection.
- Pedestrian capacity and control at station access and egress points must be considered. Where pedestrian-actuated traffic signals are provided, they shall be designed to regulate pedestrian crossings of the roadways and LRT tracks. Pedestrian push buttons shall be provided to actuate those pedestrian signals. Pedestrian signals shall display international symbols.
- Where left turns across the LRT tracks are to be controlled by a traffic signal, an exclusive left turn phase signal shall be provided.
- Priority plans, sequences, and timing shall be prepared and installed for each signalized intersection affected by light rail operations, and approved by the owning agency.
- At locations of pedestrian only signals, pedestrian push buttons shall be provided when platform access is also the crosswalk or crosswalks access station platforms. An exception is when the pedestrian phase is included in signal cycle, subject to jurisdictional approval.

10.4.2 Traffic Control Strategy

Maintaining LRT progression through the corridor is important to preserving the integrity of the LRT system. Equally important is maintaining progression on major cross street streets and intersecting LRT lines. A strategy addressing the concerns of LRT and cross street progression shall be developed by the contractor. This strategy shall include, but is not limited to:

- Analyzing LRT priority impacts to cross street traffic
- Analyzing the cross street progression on LRT operations at intersections where cross street progression is to be maintained
- Determining the extent of the analysis area (i.e., analyzing the entire downtown signal system or analyzing two blocks on either side of the LRT intersections)
- Analyzing the LRT line interaction with other LRT lines where the individual LRT lines intersect each other

- Determining if existing UTA LRT priority software has the capability to safely and adequately handle interaction between intersecting LRT lines and if it is determined that software modifications are required, make or have made the necessary software modifications
- Determining if detailed analysis/traffic signal timing plan development can be divided into geographic sections
- Incorporating findings from previously published UTA Signal System reports, such as the “SLC LRT ATMS, Task 4 Final Report” and the “Salt Lake City Light Rail Transit ATMS Final Traffic Signal & LRT Progression Analysis Report”
- Producing a final Traffic Control Strategy Report

The traffic control strategy developed shall assist in determining the level of effort required by the contractor to successfully implement LRT progression in the Salt Lake City area. The strategy shall also form the basis for developing new traffic signal timing plans to be installed into the appropriate intersection traffic signal controllers.

10.4.3 Traffic Signal Timing

New traffic signal timing plans shall be developed and implemented by the contractor, incorporating the effects of LRT priority. Work required to develop the new traffic signal timing plans shall include, but are not limited to:

- Developing signal timing and progression plans to the extent determined in the Traffic Control Strategy Report. The timing and progression plans shall be developed to the satisfaction of the agency(s) owning the signals.
- Downloading, testing, and verifying the new timing plans into the appropriate traffic signal controller.

10.4.4 LRT Detection System Analysis

Several detection technologies are available to properly detect LRT vehicles. The contractor shall review current detection technologies and analysis to determine the best and most appropriate technology to be used. This report shall include, but is not limited to:

- Determining the need for and extent of LRV detection required based on the detection requirements of the existing UTA light rail priority system and software
- A review and analysis of various in-use and proven detection technologies available
- Determining the detection technology’s ability to distinguish between LRT vehicles and other general traffic vehicles
- Determining the detection technology’s ability to eliminate “false calls” due to general traffic vehicles crossing over a LRT detector
- Determining the detection technology’s ability to distinguish between individual LRT line trains
- Determining the compatibility with the Salt Lake City Advanced Transportation Management System (ATMS) and future LRT expansion
- Determining the connectivity to the traffic signal controller(s)
- Determining the detection technology’s compatibility with the LRT priority software
- Determining the detection technology’s compatibility with the detection system installed on the North/South Line

- Determining the most effective methodology to detect a train at the beginning of the line, (e.g., countdown timers, advance detection, and interface with the block signaling system).

10.4.5 LRT Detection System Design

After an LRT detection system has been determined and approved, the detection system shall be designed. The LRT detection system design shall be coordinated with the design of the intersection traffic signal system and pedestrian crossing system. The LRT detection system design shall include, but is not limited to:

- Developing detector location layout sheets showing the detector location with respect to the LRT station and the cross street intersection, connectivity route to the traffic signal controller cabinet, general traffic vehicle detectors, and various existing utility locations
- Developing details, if any, as to how the LRT detectors connect to the traffic signal controller
- Developing details on the connection of detection system to the beginning and ending of the LRT line

10.4.6 LRT Signals

For in-street operations, LRT signals shall be provided in addition to the traffic signals controlling motorists. LRT signals shall be placed at all signalized street intersections for the sole use by light rail vehicle operators. These signals are as follows:

- Vertical bar (white)—LRV traffic proceed signal
- Diagonal bar (white)—LRV traffic proceed for turning move at route change point
- Horizontal bar (white)—LRV traffic do not proceed signal

10.4.7 LRT Priority System Testing

Prior to acceptance, the LRT priority system shall be tested to ensure the various LRT priority system elements function properly, do not adversely affect the traffic signal control functions, and properly communicate to the SLC Traffic Control Center. The LRT priority system testing shall include, but is not limited to:

- Developing a LRT Priority System Testing Plan and Procedures document. The testing plan and procedures must be approved by the appropriate agency(s) personnel and must not conflict with software or hardware manufacturer's recommended testing. The testing plan and procedures shall include requirements for testing the new traffic signal timing plans and the LRT path prediction function of the ATMS LRT software.
- Performing all appropriate LRT priority system tests, including detector communications tests and ATMS communications tests as detailed in the Traffic Signal Systems Specification.

10.5 Traffic Signal Hardware and Software

The traffic signal hardware and software requirements are as stated in the Traffic Signal Systems Specification.

10.6 Signs

Signs shall be installed in the proper locations as specified in the MUTCD and appropriate local standards. Where a sign is to be installed in a non-standard location, or is a non-standard sign, the installation shall be approved by the local jurisdiction and by UTA.

10.7 Pavement Markings

Traffic marking requirements are to be obtained from the standard plans and drawings of each jurisdiction. Where local standards are not available, the MUTCD shall be used. All pavement markings shall comply with the requirements of ADA.

END OF CHAPTER 10.



Utah Transit Authority Light Rail Design Criteria

Chapter 11 Light Rail Vehicles

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 11 LIGHT RAIL VEHICLE

11.1 General Description

This section describes the basic attributes of the light rail vehicles (LRVs) to be used by UTA. The vehicles shall be fully compatible with the existing vehicles for mixed consist operation. Information contained herein is intended to generally define the composite aspects of the vehicle which relate to the interfaces between the vehicle and other portions of the UTA light rail system. Because the vehicle is a composite of “off-the-shelf” equipment, these criteria apply to the limits that the design of available equipment must meet. In turn, the actual vehicle must generate criteria affecting traction power and structural detailed design, and this data should be available promptly after the procurement is decided. Until that decision is rendered, the following LRV criteria shall apply with the understanding that changes will be forthcoming when the specific actual vehicle is defined.

11.2 Vehicle Environment

11.2.1 Environmental Criteria

Refer to Chapter 2, Environmental Criteria.

11.2.2 Wayside Characteristics and Civil Alignment Constraints

Refer to Chapter 3, Track Alignment and Vehicle Clearance.

11.2.3 Overhead Contact System (OCS) Power Interface

11.2.3.1 Traction Power Interface

- Nominal OCS voltage: 750 volts, DC
- Maximum operating voltage: 900 volts, DC
- Minimum operating voltage: 525 volts, DC

11.2.3.2 Vehicle Voltage Limits

The vehicle upper voltage limit shall be set to maximize the benefits of regeneration, but not to exceed 950 volts DC. The vehicle equipment shall be designed to operate at a lower limit of 450 volts DC. All equipment shall be capable of operating without damage at any voltage between these two limits. Outside of these limits, vehicle systems shall be shut down, which shall cause an emergency brake application.

11.3 Vehicle Design Constraints

11.3.1 Safety Requirements

Items, the failure of which could result in critical/catastrophic hazard, are designated “safety critical.” A critical/catastrophic hazard is a situation which could result in an injury or fatality to patrons or UTA personnel, or which could result in major damage to or a loss of a vehicle function or equipment.

Specific safety critical items identified for the vehicle are:

- Removing positive tractive effort during braking
- Braking and safe braking distances

- Prevention of initial motion with any brake applied
- Fire-resistance requirements
- Inhibiting motion when doors are open
- Prevention of door opening during motion
- Direction control
- Automatic train protection (to be considered as an option)

The vehicle contractor shall identify any additional safety critical items incorporated in its proposed design.

11.3.2 Shock and Vibration Criteria

All car components shall operate without damage in the normal rail environment and shall not produce excessive vibrations. Equipment design and mounting arrangements shall be based on a specific mounting location on the car and shall consider the influence of adjacent components as well as normal vehicle operation. In addition to any shock or vibration encountered in normal operation, all equipment shall withstand the vibration levels defined in the following sections and, under these specified conditions, shall not cause vertical or horizontal vibrations anywhere on the vehicle floor, walls, ceiling, panels, and seat frames in excess of the following:

- Below 1.4 Hz—Maximum deflection (zero to peak) of 2.5 mm (0.10 inch), based on insuring that the vibration of the car body elements are not sensed by patrons
- Between 1.4 Hz to 20 Hz—Maximum peak acceleration of 0.01 g (vibrations of this amplitude may be perceptible, but not uncomfortable to patrons)
- Above 20 Hz—Maximum peak velocity of 0.75 mm/sec. (0.03 in/sec.); this limit is primarily designed to limit noise radiated from vibrating car body components

In addition, the vibration of any traction motor shall conform with the requirements of IEEE Standard No. 11, Sections 13.2.2 and 13.2.3.

11.3.2.1 Car Body Mounted Components

These components shall be designed and mounted to withstand:

- Continuous sinusoidal vibrations of 0.4 g rms at any frequency from 1 Hz to 100 Hz in the three major axes
- Randomly oriented shock impulses of 3 g peak with duration from 4 milliseconds to 10 milliseconds

11.3.2.2 Truck Frame Mounted Components

These components shall be designed and mounted to withstand, without fatigue or deterioration for a vehicle life of 30 years, the normally occurring random shock and vibration magnitudes at the support points on the truck frame. These magnitudes shall be considered to be 1.0 g rms with a crest factor (ratio of peak to rms acceleration level) of 5, within the frequency range from 20 Hz to 10 kHz in all directions, and shocks occurring up to 100 times per operating day to 20 g peak in the vertical axis and 6 g peak in the lateral axis with pulse durations from 4 milliseconds to 10 milliseconds.

11.3.2.3 Axle-Mounted Components

Components shall be designed to withstand, as a minimum:

- Continuous random vibrations of 10 g rms within the frequency range of 10 Hz to 10 kHz in all directions
- Shock pulses of 100 g in each major axis, with durations from 0.5 milliseconds to 2 milliseconds occurring approximately 100 times per day

11.3.3 Weight Constraints and Design Loading

As a baseline, the composite vehicle shall not weigh more than the following:

- AW0 (Empty Car) 43.1 metric tons (98,000 lb)
- AW1 (Seated Load) AW0 + 75 passengers at (111,000 lb) each
- AW2 AW1 + 90 standees (125,000 lb)
- AW3 AW2 + 45 standees (132,000 lb) = 61.7 metric tons (136,000 lb)
- AW4 (Crush) AW3 + 45 standees (139,000 lb)

The minimum acceptable number of seats per vehicle is 60.

Equipment installation shall be arranged such that its weight is evenly distributed to the maximum practical extent. The vehicle, complete with all necessary apparatus, shall meet the following criteria:

- The difference of static weight, as measured under each motor truck, shall not be greater than 2%.
- The difference of static weight between the A-end and B-end of the vehicle shall not exceed 900 kg (2,000 lb).
- The lateral imbalance shall not exceed 290 kg-m (25,000 in-lb).

11.3.4 Vehicle Identification

Vehicles shall be sequentially numbered from the first production car to the last.

11.3.5 Acoustic Noise Limits

11.3.5.1 Wayside Noise Limits

Wayside noise produced by a two-car consist with all auxiliary systems operating shall not exceed the following limits:

- At 90 km/h (55 mph) 80 dBA at 15 m (50 ft)
- At 32 km/h (20 mph) 68 dBA at 15 m (50 ft)
- Each auxiliary system alone 67 dBA at 4.6 m (15 ft)
- Vehicle stationary 60 dBA at 15 m (50 ft)

11.3.5.2 Car Interior Noise Limits

The average noise level in the interior of the car shall not exceed the following levels with all equipment operating:

- At 90 km/h (55 mph) 72 dBA
- At 64 km/h (40 mph) 70 dBA

- Vehicle stationary 68 dBA

11.3.6 Electromagnetic Compatibility

Harmonic currents produced by the vehicle in the running rails shall not exceed 30% of the minimum guaranteed threshold of the associated signal circuits. Signal circuits shall have a fundamental frequency of 100 Hz. Audio frequency overlays shall also be used for at-grade crossing protection.

Electrical, electronic, and communications systems and sub-systems shall operate without either suffering or causing interference which may impact system operations and/or safety because of electromagnetic interference.

11.3.6.1 Radiated Emission Limits

Vehicles shall not produce any radiated emissions that will violate FCC Rules and Regulations, Part 15.25. For design validation, vehicles shall not produce radiated emission levels above those permitted by Figure 10-2 (UM05), Curve 2 of MIL-STD-461B, when measured at 30.5 m (100 ft) from the track centerline and tested in accordance with UMTA-MA-06-0153-85-11.

- From 0.01 MHz to 30 MHz, the maximum permissible interference limit shall not exceed 20 dB above the limit of Figure 22 (RE05) of MIL-STD-461A.
- From 30 MHz to 88 MHz, the maximum permissible interference limit shall be 58 dB above 1 mV/m/MHz bandwidth.
- From 88 MHz to 1,000 MHz, the maximum permissible interference limit shall be 68 dB above 1 mV/m/MHz bandwidth.

11.3.6.2 Conductive Emission Limits

- From 0 Hz to 40 Hz, 10 A maximum
- From 40 Hz to 120 Hz, 1 A maximum
- From 120 Hz to 320 Hz, 10 A maximum
- Above 320 Hz, the maximum permissible conductive emission limits shall be under a smooth curve through 10 A at 320 Hz, 0.08 A at 2 kHz, and 0.0046 A at 7 kHz

11.3.6.3 Inductive Emission Limits

The inductive emissions shall be limited to a maximum of 20 millivolts rms, rail-to-rail, at all frequencies between 20 Hz and 20 kHz.

11.3.6.4 Susceptibility

All systems shall be designed and installed to tolerate acceptable levels of electromagnetic interference and have adequate protection against false energization, miscodes, and improper codes caused by any and all electromagnetic emission sources.

11.3.7 Smoke and Flammability Requirements

All materials and construction shall meet the requirements of the latest edited version of NFPA 130, Chapter 4, Vehicles, and related appendices.

The ceiling structural assembly shall meet a 30-minute minimum endurance rating when tested in accordance with ASTM E 119. The floor structural assembly shall meet a 15-minute minimum endurance rating when tested in accordance with ASTM E 119.

Total BTU content shall be no more than 90,000,000 BTU per vehicle. Heat release rate shall be no more than 45,000,000 BTU/hour per vehicle.

11.3.8 Provisions for Individuals with Disabilities

Provisions for individuals with disabilities shall be per the rules and regulations of the Americans with Disabilities Act (ADA) effective October 7, 1991, and shall comply with all applicable requirements for new transit facilities. Only the minimum requirements for design and construction are incorporated into the ADA Accessibility Guidelines. Related regulatory provisions of other government agencies having jurisdiction shall be used for additional guidelines in designing and constructing light rail vehicles to be free of architectural or other transportation barriers.

The latest editions of the code, regulation, and standard that are applicable at the time the design is initiated shall be used. If a new edition or amendment to a code, regulation or standard is issued before the design is completed, the design shall conform to the new requirements to the extent practical, except that it shall conform to the new requirements if required by the government agency enforcing the revised or new code, regulation, or standard.

Reference:

- Federal Register 49 CFR Parts 27, 37 and 38, Transportation for Individuals with Disabilities, Final Rule
- U.S. Architectural and Transportation Barriers, Compliance Board, Technical Assistance Manual

11.3.9 Lighting Safety Provisions

All exterior lights and emergency interior lighting shall be capable of operating from battery power for up to 60 minutes in the event of an auxiliary power supply failure.

11.3.10 Ride Quality

The vehicle design shall be free from objectionable vibration and shock. All equipment mounted in the passenger area shall be free from resonance to avoid audible and visual annoyance.

The ride quality shall be evaluated according to ISO 2631. The rms acceleration values shall not exceed the “2½ to 4 hours reduced comfort level” boundaries derived from Figure 2a (vertical) and Figure 3a (horizontal) of ISO 2631-1978 (E).

The roll stiffness of the vehicle body, when subjected to lateral accelerations, shall not exceed 20 dpg (degrees per g).

11.3.11 Adhesion Requirements

The vehicle adhesive weight and the efficiency of the slip/slide system shall be such that the adhesion required by the positive tractive force to start a vehicle from a standstill anywhere on the system, and the adhesion required by the negative tractive force to decelerate the car from any speed down to a standstill, will not cause unacceptable damages to the vehicle wheels under track slippery conditions.

Track slippery conditions are defined as those conditions which may cause the actual coefficient of adhesion to be, without sanding, less than 20% but not less than 10%. With sanding, track slippery conditions are defined as those conditions which may cause the actual coefficient of adhesion to be less than 28%, but not less than 17%.

11.4 Light Rail Vehicle Dimensions

11.4.1 Exterior Dimensions

Vehicle dimensions shall not exceed the following (all heights are from top of rail):

- Length over the coupler faces 26,975 mm (88.5 ft)
- Exterior width 2,650 mm (104 in)
- Car floor height (nominal) 1004 mm (39.5 in)
- Top of roof mounted equipment 3,800 mm (150 in)
- Top of pantograph in locked down position 3,730 mm (146.85 in)

11.4.2 Other Dimensions

- Ceiling height from floor 2,083 mm minimum (82 in)
- Width of side door openings 1,220 mm minimum (48 in)
1,320 mm maximum (52 in)
- Height of side door openings 1,930 mm minimum (76 in)
- Pantograph operating range 4,064 mm minimum (13 ft 4 in)
7010 mm maximum (23 ft)
- Wheel diameter (new) 710 mm (28 in)
- Wheel diameter (worn) 660.4 mm (26 in)

11.4.3 Dynamic Outline

Minimum under-car clearances under worst case vertical curve crest and sag (for minimum radius of vertical curve, see Chapter 3), worst case loading and worst case wheel wear shall be as follows:

- Under-car mounted equipment 101.6 mm (4 in)
- Under-truck mounted equipment 63.5 mm (2.5 in)

For OCS design purposes, vehicle dynamic movements shall be constrained within the following limits:

- Maximum body roll during normal operation 6 degrees (3 degrees to each side)
- Maximum pantograph sway with respect to car body during normal operation at 5,791 mm (19 ft) +/- 50.8 mm (2 in) with pantograph
- Lateral bearing displacement +/- 50.8 mm (2 in)

11.5 Vehicle Performance

LRV performance is defined for operations on dry level tangent track, AW2 loading for acceleration performance and AW3 loading for deceleration performance, over the specified range of wheel wear, with no significant wind. OCS voltage shall be at the nominal 750 Vdc for propulsion. In braking, the braking system shall perform as specified at any line voltage within the specified range.

Dry track conditions are defined as those conditions where the actual coefficient of adhesion is at least 25% without sanding.

11.5.1 Acceleration Requirements

- Acceleration rate (initial) from 0 to 32 km/h (20 mph) 1.34 m/s/s (3 mph/s)
- Time to 32 km/h (20 mph) 8.5 seconds maximum
- Time to 90 km/h (55 mph) 40 seconds maximum

11.5.2 Speed Requirements

- Minimum balancing speed 90 km/h (55 mph)
- Maximum operating speed 92 km/h (57 mph)
- Nominal operating speed 0 km/h (55 mph)

11.5.3 Deceleration Requirements

- Minimum average safe service brake rate 0.67 m/s/s (1.5 mph/s)
- Average service brake rate from 90 km/h (55 mph) to 64 km/h (40 mph) 1.07 m/s/s (2.4 mph/s)
- Average service brake rate from 64 km/h (40 mph) to 4.8 km/h (3 mph) 1.34 m/s/s (3 mph/s)
- Average service brake rate from 4.8 km/h (3 mph) to 0 0.67 m/s/s (1.5 mph/s)
- Average emergency brake rate from 90 km/h (55 mph) to 48 km/h (30 mph) 1.78 m/s/s (4 mph/s)
- Average emergency brake rate from 48 km/h (30 mph) to 0 2.00 m/s/s (4.5 mph/s)

11.5.4 Towing Requirements

A fully functioning train shall be capable, with no damage to its equipment, of pushing or pulling an inoperative train of the same length, with both trains loaded at AW3. An inoperative train is defined as a dead train. Due to the reduced adhesive weight, the acceleration rate can be reduced to the limits required to operate in accordance with the track characteristics. The deceleration rate can also be reduced, but not to be less than the safe braking rate. Under slippery track conditions, sanding may be used to make the actual adhesion at least equal to the adhesion required by either the positive tractive force during the propulsion mode, or the negative tractive force during the braking mode.

11.5.5 Jerk Limit

Under all normal operating conditions, the rate of change of vehicle acceleration or deceleration shall not be less than 0.89 m/s/s/s (2 mph/s/s) or greater than 1.34 m/s/s/s (3 mph/s/s).

Failure of the jerk limiting system shall not limit the braking effort. Emergency brake applications and any associated ramp out of propulsion shall not be jerk-limited. Reduction of propulsion effort due to power interruption does not need to be jerk-limited. Reapplication of propulsion effort following a power interruption shall be jerk-limited.

11.5.6 Slip/Slide Protection

A slip/slide protection system shall be provided. A slip/slide protection system is defined as a system which reduces the tractive effort, either positive during propulsion or negative during braking, upon detection of a slip or a slide and until the slip or the slide disappears. Ideally, the reduction of tractive effort would bring the required coefficient of adhesion down to the same value as the actual coefficient of adhesion.

The efficiency of the slip/slide system shall be at least 75% on a slippery track with an adhesion coefficient of 10%, when operating with friction brake only in either service braking or emergency braking.

11.5.7 Load Weight System

A load weight system shall be provided. The load weight system shall provide the vehicle load information to the propulsion and braking systems, in order for the propulsion system to achieve the required acceleration from AW0 to AW2 and for the braking system to achieve the required deceleration from AW0 to AW3.

11.6 Car Body

The car body shall be constructed of low alloy high tensile (LAHT) steel. All exterior surfaces of the LAHT steel shall be primed and painted. All interior metal surfaces shall be coated with a primer for corrosion protection. Vehicle end caps may be fabricated using molded fiberglass.

11.6.1 Strength Requirements

The yield strength of all structural members shall withstand a uniform vertical load of AW3 minus AW0 with at least a 50% margin.

The vehicle shall withstand a static compression end load of two times AW0 acting along the longitudinal centerline of the vehicle and distributed at about the center of the anticlimber.

The combined stresses from the above vertical load and the above static compression end load shall not cause any deformation in any part of the car body and shall not exceed 90% of the yield value of the material used.

Each anticlimber shall have at least three ribs.

11.6.2 Roof

The roof sheathing and structure shall be capable of supporting without any permanent deformation concentrated loads of at least 113 kg (250 lb), as would be applied by a person walking on the roof. Areas adjacent to the pantograph shall support concentrated loads of at least 227 kg (500 lb).

A roof mat shall be installed on the roof to provide an anti-slip walking surface. In addition, an electrically insulated area on the roof, under and around the pantograph mounting, shall be installed to provide a safe working area for maintenance personnel.

11.6.3 Jacking and Hoisting Provisions

The vehicle shall be equipped with jacking and hoisting provisions. The vehicle may be jacked as a unit. Each body section may be jacked separately, with the body bending at the articulation section(s). The maximum angle of bending of the articulation shall not exceed 3 degrees. Any combination of diagonal jacking shall not cause any structural or cosmetic damage.

Jacking pads shall be provided for:

- Portable jacks
- In-floor hoists
- The articulation

Jacking at the anticlimber positions shall be permitted.

The vehicle design shall include provisions for re-railing the center truck.

11.6.4 Wheelchair Accommodations

Provisions shall be made to comply with the latest ADA requirements.

11.7 Couplers and Draft Gear

11.7.1 Mechanical Couplers

Couplers shall automatically couple on contact within a gathering range of 76 mm (3 in) and with a maximum of 8 degrees of total rotational mismatch.

Couplers shall withstand AW0 car coupling at speeds up to 4.8 km/h (3 mph) without automatic release or damage.

The coupler system shall withstand a buff or draft load of 79.38 metric tons (175,000 lb) with no permanent deformation.

11.7.2 Draft Gears

At buff or draft loads above 68.04 metric tons (150,000 lb), draft gears shall collapse to allow the anticlimbers to meet while absorbing the moment resulting from the load.

11.7.3 Electrical Couplers

Spring-loaded silver-plated contacts, which are redundant on each side of the coupler, shall carry all necessary electrical signals from car to car.

Electrical couplers shall use a mirror image configuration such that any end of any car can be coupled to any end of any other car.

Electrical coupler heads shall be protected by weatherproof covers, which shall automatically swing clear when a coupling is initiated.

11.8 Operator's Cab

There shall be two completely functional operator's cabs per car. Trainline control shall permit only one cab to act as the active controlling cab in a train consist.

The operator's cab shall be of a design based on appropriate human factors. The operator's cab dimensions shall ensure safe and optimal operator performance for operators in the range of the 5th to 95th percentile of the general population, both female and male.

11.8.1 Operator's Console

The operator's console shall contain all controls and annunciators to safely operate the train.

11.8.2 Bypass and Cutout Switches

One panel within each operator's cab shall contain sealed safety bypass switches that shall permit manual operation of the train in the event of failure of major subsystems. An adequate annunciation shall be provided to clearly indicate to the operator which bypass switch is in a bypass position.

11.9 Passenger Doors

There shall be four passenger doors per side in each car.

Door operators shall be electrically operated.

The door opening function shall be interlocked with the propulsion and brake systems, such that motion is not permitted when any door in a train consist is not fully closed, and such that brakes are applied when the door opening function is enabled by the operator or any door in a train consist is not fully closed.

11.9.1 Normal Operation

Doors shall normally be opened individually by passenger-operated push-buttons, after release (enable function) by the train operator after the train stops at a station. The operator shall normally control the closing of the doors. In addition, the operator shall have the capability of controlling opening and closing of the doors on either side of the train.

11.9.2 Emergency Operation

An emergency manual door release shall be provided near each door.

Activation of the emergency door release device shall unlock the door for manual opening, prevent motion, and place the train in an irretrievable full service brake application. In addition, any attempt to activate an emergency door release device in motion shall reapply closing power to the door at that location in order to prevent its manual opening.

11.10 Air Comfort System

The air comfort system shall include heating, ventilating, and air conditioning to assure passenger comfort in the operating environment. The air comfort system shall be equipped with a single control unit. Maximum interior relative humidity shall not exceed 55%.

Except in layover mode where the ventilation shall not be used, ventilation shall be provided all the time to ensure that a minimum comfortable amount of fresh air is delivered to the vehicle.

The heating system shall include overhead and floor heaters in the passenger compartment, and cab heaters in the operator's cabs. The heating system shall be designed to maintain the interior temperature around 20 °C (68 °F). The heating system shall also be provided with a "layover" mode. In the layover mode, a selected number of floor heaters shall be used to maintain the interior temperature around 13 °C (55 °F). In the layover mode, the car interior temperature shall be controlled by a separate layover thermostat. Heated surfaces which may come in contact with passengers shall not exceed 51.7 °C (125 °F).

With an exterior ambient temperature of 23 °C (73 °F) to 35 °C (95 °F), the air conditioning system shall maintain the vehicle interior temperature between 23 °C (73 °F) and 26 °C (78 °F). With exterior temperatures above 35 °C (95 °F), the vehicle interior temperature shall be at least 9 °C (17 °F) lower than the outside temperature.

The air conditioning units shall be mounted on the vehicle roof and may be individually controlled by the single air comfort control unit.

11.11 Lighting System

The lighting system includes all interior and exterior lights, with the exception of annunciator lights.

11.11.1 Interior Lighting

The passenger compartment shall be lit by continuous fluorescent lighting fixtures, which shall not extend into the operator's cabs.

The operator's cabs shall be lit by separately controlled lamps.

11.11.2 Exterior Lighting

All exterior lights shall be trainlined for proper illumination and identification at night.

The vehicle shall be equipped with three headlights, two taillights and three stoplights at each end. The center headlight shall be a 200-watt PAR 56 railroad lamp. The stoplights shall operate at approximately 150% of the intensity of the taillights.

For joint freight/LRV operation, exterior lighting shall be in compliance with the requirements agreed upon between UTA and FRA.

11.11.3 Emergency Lighting

The emergency lights shall be all exterior lights, all cab lights, all lights above the doors, and 25% of the interior lights.

The emergency lights shall remain functional for at least 60 minutes in the event of a failure of the auxiliary power supply using battery power back-up.

11.12 Auxiliary Electrical Equipment

11.12.1 Power Collection

Power from the overhead contact system shall be collected by a roof-mounted pantograph which uses a double shoe arrangement of proven service design. The double shoe arrangement shall include a spring-loaded suspension. A lateral load of 29.50 kg (65 lb) on the pantograph shoe axis with the pantograph at the maximum operating height shall not cause the shoe to deflect more than 38 mm (1.50 in). The pantograph shall be mounted as close as possible from the center of the vehicle to minimize lateral movement under all track conditions. A breakaway design shall be used so that the pantograph is sacrificial to the overhead wire in case of snagging.

The pantograph shall be raised by a spring, with an appropriate damping device to minimize bouncing. The upward contact force shall be approximately 7.25 kg (16 lb).

The pantograph shall be electrically lowered and latched. An electrically released lock-down mechanism shall be provided to prevent movement of a locked pantograph.

Means shall be provided to manually release the lock-down mechanism, and raise, lower, and latch the pantograph from inside the vehicle if electrical power is not available.

The pantograph design shall include provisions for clearing ice from the OCS. The pantograph may be unpowered while clearing ice.

11.12.2 Auxiliary Power Supply

A variable duty cycle static inverter shall be provided to develop 3 phase 60 Hz 208/120 V auxiliary power from the 750 Vdc primary power. The voltage regulation shall be within $\pm 5\%$, and the frequency shall be maintained within ± 5 Hz. Alternatively, the voltage-to-frequency ratio should be maintained within $\pm 1\%$ at all loads. Capacity shall be sized to handle worst case loads for any season or operating conditions with an additional 10% margin.

11.12.3 Low-Voltage DC Power Supply

A nominal 37.5 Vdc low-voltage power supply (LVPS) shall be provided to power systems and subsystems controls, exterior lighting and annunciators, and door operators.

In addition, the LVPS shall also maintain the storage battery charge. Output of the LVPS shall be regulated within $\pm 10\%$ from zero to full load.

11.12.4 Storage Battery

A nickel-cadmium battery shall be provided to initially start the vehicle and to power emergency loads during failures of the LVPS or when the primary 750 Vdc power is lost. The capacity shall be sufficient to power emergency loads for at least 1 hour of operation.

11.12.5 Emergency Loads

Emergency loads are defined as follows:

- Emergency lights (see Section 11.11.3)
- Doors
- Communications
- Propulsion and braking controls
- Trainline controls
- Track brake(s)
- Pantograph
- Coupler control
- Cab lighting, controls, and annunciators
- Horn(s)
- ATP (as an option)

11.13 Propulsion System

11.13.1 General

The propulsion system shall conform to one of the following configurations:

- Sweeping frequency thyristor chopper with DC traction motors
- Fixed frequency thyristor chopper with DC traction motors
- AC inverter control with AC traction motors

The requirements for an AC propulsion system shall include a variable voltage, variable frequency voltage source microprocessed controlled 3-phase inverter using pulse width modulation and square wave regulation techniques. Inverters shall use modular construction technique based on a limited number of individual building blocks. At least one inverter per motor truck shall be provided.

The propulsion system shall have the following characteristics:

- Separate and independent slip/slide control for each powered truck
- Separate and independent slide control for the unpowered truck
- Separate friction brake interface and brake blending control for each truck
- Design and construction of all AC traction motors, gear units, and power conditioning equipment such that a 804,500 km (500,000 miles) overhaul cycle is achieved without intermediate maintenance activity beyond routine inspection and servicing
- Ability to operate cars successfully and reliably on the OCS with high-voltage transients and extensive arcing and repetitive occurrences of intermittent contact
- Ability to continue operations for extended periods of time with reduced acceleration and safe braking rate when a powered truck is cut out

11.13.2 Drive Configuration

Drive systems shall be configured with one motor per axle on each powered truck, using a resiliently mounted parallel gear drive arrangement with overspeed protection. The maximum motor speed shall allow continuous operation at 92 km/h (57 mph) with fully worn wheels on a level tangent track.

All motors, gear units, and couplings shall be fully interchangeable from motor axle to motor axle and between powered trucks.

Gears shall have a minimum life of 1,609,000 km (1,000,000 miles), and shall be fabricated from high quality gear steel designed and treated/hardened in accordance with AGMA 240.01–Gear Material Manual.

11.13.3 Continuous Rating

The propulsion system continuous rating shall be based on the worst case continuous duty cycle derived from the route profile, and stop/start operation in mixed traffic and extended operation at extreme OCS voltages. The continuous thermal rating shall be determined for an AW2 loading level and shall provide a margin of at least 10% above that required for continuous duty cycle, to include the ripple power amplitude and the ripple frequency present on the inverters.

11.13.4 Short-Time Overload Rating

The short-time overload rating for the propulsion system shall be determined as follows:

- Following operation of a two-car train with AW2 loads for 2 hours under the continuous rating conditions specified in Section 11.13.3, the propulsion system shall be capable of continuing operation for 1 more hour with one car in cutout, without exceeding component temperature ratings.
- Following operation of a four-car train with AW2 loads for 2 hours under the continuous rating conditions specified in Section 11.13.3 followed by a dwell time of 1 minute, the propulsion system shall be capable of accelerating under full acceleration from 0 to 90 km/h (0 to 55 mph), and of braking from 90 km/h to 0 (55 mph to 0) with electric braking only (except that below the fade out speed, friction braking will be used) three times repetitively with a dwell time of 20 seconds between each cycle, without exceeding component temperature ratings.
- The propulsion system shall also have the capability of towing or pushing a dead train of equal length, without exceeding component temperature ratings. The contractor shall provide the subsequent performance restrictions for approval by UTA.

11.13.5 Electric Braking

Electric braking shall be sufficient to meet the required performance without any addition of friction braking for loads up to and including AW2, at all speeds from 90 km/h (55 mph) down to the electric brake fade out speed (approximately 4.8 km/h, or 3 mph).

In the double track areas, if the overhead contact system is receptive to regenerative current such that the propulsion system exceeds an internally set limit, electric braking shall be blended between regenerative and rheostatic braking, with priority to regenerative braking.

Above AW2 load, electric braking shall be blended with friction braking in order to provide the required performance up to and including AW3.

11.13.6 Cooling

If required, cooling air for traction motors shall be ducted and screened from the side of the car body, sufficiently high above the top of rail to minimize the entry of snow and road dust.

Cooling air for power semi-conductors, if used, shall not come in contact with energized components or surfaces. Chlorinated fluorocarbon cooling methods shall not be used.

11.13.7 Ground Brush

Each axle of all trucks shall be provided with two ground brushes and holders.

Ground brush life shall be a minimum of 241,350 km (150,000 miles).

11.14 Trucks and Suspension

The vehicle shall be supported by three two-axle trucks (two motor trucks and one trailer truck), with a coil spring secondary suspension. The primary suspension shall be by means of chevron or approved equivalent elastomeric springs, with a maximum vertical resonant frequency of 12 Hz.

Trucks of proven design shall be connected to the car body through positive mechanical means such that the trucks shall be raised with the car body when it is lifted.

11.15 Friction Braking System

The friction braking system shall be an electro-hydraulic disc brake system. One hydraulic power unit per truck shall be provided.

11.15.1 Service Braking

Friction braking shall act as a supplement to the electric braking below the electric brake fade out speed and at loads above AW2. Above AW2, friction braking and electric braking shall be blended to provide the required braking rates.

Friction braking only shall be used in case of unavailability of electric braking. In that case, friction braking shall be capable of providing the required service brake rate at any speed and for all loads up to AW3.

A parking brake system shall be provided that is capable of holding an AW0 vehicle on a 4% grade for 30 days with no electric power available on the vehicle.

11.15.2 Emergency Braking

Friction braking shall be the primary braking system for emergency stops. Emergency braking shall include track brake application and sanding, as required to meet the specified emergency brake rates.

11.16 Communications System

The communications system shall be composed of the train radio, the public address system and the intercom.

11.16.1 Train Radio

The train radio system shall be completely integrated with the vehicle. The radio system shall allow communications between the train operator and the controller.

The radio shall be capable of transmitting an operator-initiated silent alarm.

11.16.2 Public Address System

The public address system shall allow the train operator to make announcements to passengers inside the train, and to persons waiting outside on the platform when the train is in a station.

11.16.3 Intercom

The passenger intercom system shall allow a two-way conversation between the train operator and any of the energized on-board passenger intercom stations. There shall be two passenger intercom stations in each car, located at each end near each wheelchair position.

11.17 Automatic Train Protection

As an option, automatic train protection may be used. Train control circuits shall use 100 Hz signals for block signaling, and audio frequency overlays at grade crossings. Additionally, a train to wayside communications system may be used. The LRV shall be designed not to interfere with these applications.

11.18 In-Service Support

11.18.1 General

As a minimum, the in-service support shall include:

- Manuals
- Shop and portable test equipment and special tools
- Initial spare parts and recommended parts stocking level
- Training
- Acceptance testing
- Warranty

11.18.2 Manuals

Operating manuals shall be provided and shall include:

- General familiarization with the vehicle
- Operation of the vehicle
- Trouble symptoms and diagnostic methods
- Recovery procedures
- Emergency procedures

Maintenance manuals shall be provided and shall include “running maintenance manuals” and “heavy repair maintenance manuals.”

Running maintenance manuals shall provide:

- Information required to perform on-board servicing, and periodic servicing and adjustment
- Trouble diagnosis, to include troubleshooting guides
- Piping and wiring schematics
- Information required for using test equipment and special tools

Heavy maintenance manuals shall contain detailed descriptions and analyses of components, such that maintenance personnel can effectively repair, replace or overhaul each component and subsystem.

Parts Catalogs shall also be provided. Parts catalogs shall identify each component and shall give its contractor's part number, suppliers, source control documents, and drawings.

The format and content of each of the above documents and the number of copies to be provided shall be submitted by the contractor for UTA approval.

11.18.3 Shop and Portable Test Equipment and Special Tools

The contractor shall provide all necessary special test equipment and special tools for UTA personnel to properly perform in-service maintenance, testing, and adjustment.

11.18.4 Spare Parts

The contractor shall deliver spare parts such that the delivery shall be keyed to the vehicle delivery schedule and will provide a sufficient inventory to support the operating needs of UTA at all times until the expiration of the warranty period.

The contractor shall also determine the final inventory required to support on-going car maintenance after the expiration of the warranty period. The subsequent recommended final spare parts list, including detailed costs, shall be submitted to UTA sufficiently in advance in order for UTA to complete the recommended stocking level before the expiration of the warranty period.

11.18.5 Training

The contractor shall provide a training program for a sufficient number of selected UTA instructors, supervisors, operations personnel, and maintenance personnel, of a quality and depth sufficient to permit UTA to safely and satisfactorily operate, service, and maintain the vehicles, and to train other and future staff in the operation and maintenance of the vehicles. The training program shall be conducted at UTA facilities, and should include classroom and "hands-on" instruction.

The contractor shall, within 90 days after award of the contract, submit a training program outline and a schedule for UTA approval that shall identify milestones for submitting the course outlines, lesson plans, instructor and student guides, audio-visual aids, mock-up(s), simulator(s), written and practical tests, and conducting classes.

As training materials are being developed, the contractor shall work closely with UTA staff to ensure UTA standards, with respect to the training program organization, content, and overall quality of training aids are met.

All training materials shall become the property of UTA at the completion of the training program. The contractor shall be responsible for the condition of these materials for the duration of the training program, and shall replace all damaged materials unless the damage resulted from neglect by UTA personnel. Written and audio-visual training aids shall be updated as required.

11.18.6 Acceptance Testing

11.18.6.1 General

After all qualification and quality control tests have been successfully completed by the contractor prior to shipment of the vehicle(s) to UTA, acceptance testing shall be performed at UTA facilities by the contractor, prior to delivery of the cars to UTA for final acceptance, and by UTA for final acceptance of the vehicles. The purpose of these tests is to verify that no damage has occurred during shipment and to ensure that cars are properly adjusted and in suitable conditions for operation by UTA in revenue service.

Test procedures shall be submitted to UTA for approval.

UTA will, at its option, witness all tests performed by the contractor. Therefore, the contractor shall notify UTA, in writing and at least two weeks prior to each test, of the date, time, and location the test will be performed.

11.18.6.2 Pre-Delivery Acceptance Testing

After receipt of each car at UTA's facilities, and before it is operated, it shall be jointly inspected by UTA and the contractor. The contractor shall make such adjustments, repairs, or replacements as required for proper operation before pre-delivery acceptance testing may begin. Should a repair or replacement be required which is a result of inadequate pre-shipment testing, the contractor shall provide UTA with evidence that the inadequacy is corrected prior to shipment of additional vehicles.

As a minimum, the following pre-delivery acceptance tests shall be performed by the contractor:

- Insulation resistance and high potential tests
- Functional tests (all subsystems)
- Coupler tests (alignment and level)
- Static clearance tests (trucks and carbody)
- Interface tests with other systems (track, OCS power, and ATP)
- Dynamic clearance tests

11.18.6.3 Pre-Delivery Performance Testing

After successful completion of the pre-delivery acceptance tests, the contractor shall demonstrate the dynamic performance of each vehicle, as specified in Section 11.5, and that all design constraints have been satisfied, as specified in Section 11.3.

After successful completion of the pre-delivery performance testing on the first four cars, compliance with the towing requirements specified in Section 11.5.4 shall be demonstrated by the contractor only once, using two active cars and two dead cars.

11.18.6.4 Final Acceptance Testing

After successful completion of the pre-delivery acceptance and performance testing on the first car, cars having successfully completed their pre-delivery testing shall be delivered to UTA for final acceptance testing.

In order to facilitate and support the UTA final acceptance testing program, the contractor shall provide UTA with the instrumentation required to monitor at least two cars, the procedures to connect and use the instrumentation, and the technical support which may be required until completion of the final acceptance program.

Each car will be given an operational “burn in” of about 1,600 km (1,000 miles) by UTA. During “burn-in,” performance, current and voltage parameters, as well as date, time, and distance will be recorded continuously on separate channels on magnetic tapes. Upon issuance of a notice of rejection by UTA, rejected cars will be turned back to the contractor for appropriate corrective actions. After the contractor has completed its corrective work, UTA will complete retesting of the cars.

11.18.7 Warranty Period

The contractor shall submit for UTA approval its plan to show how it intends to support UTA during the warranty period.

The duration of the warranty period shall be clearly stated. The cost of the warranty period shall be included in the vehicle contract price. If applicable, optional additional extended warranty periods with their associated costs may be proposed by the contractor.

END OF CHAPTER 11.



Utah Transit Authority Light Rail Design Criteria

Chapter 12 Electric Traction Power Supply and Distribution System

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 12 ELECTRIC TRACTION POWER SUPPLY AND DISTRIBUTION SYSTEM

12.1 Introduction

These criteria include functional and design requirements for the supply and supervision of traction power for light rail transit.

The light rail vehicles, as described in Chapter 11, shall be propelled by electric traction motors driving steel wheels through the appropriate gearing. Electric traction power shall be supplied to the vehicle from wayside substations through an overhead contact system distributing power through a contact wire installed over each running track, upon which a pantograph collector on each car shall maintain contact. Both running rails of each track shall be used for the traction power negative return, except at crossovers or other locations as determined.

The traction power system shall supply sufficient power to transit vehicles for the safe, efficient, and continuous operations of the transit system. Design of the traction power system shall be coordinated with the electric utility companies who shall be provide primary power for the system.

The traction power system design shall be coordinated with other subsystems (e.g., vehicles, civil works, signaling, and communications) including vehicle propulsion and power control operating tolerances. The vehicle auxiliaries shall accept the full range of traction power voltage variations.

12.2 Requirements

The elements described in the following sections shall be included in the traction power supply and distribution system.

12.2.1 Traction Power Substations

The traction power substation consists of all equipment between the interface point with the electric power utility and the interface point with the DC feeder system. Each substation includes AC cables, utility metering equipment, AC switchgear, transformer/rectifier units, DC switchgear, positive and negative busbars, negative drainage panel, substation housing, grounding system, negative return system, relay protection system, auxiliary power supply system, heating and ventilation inside the substation, batteries and charger, security system, lightning arresters, and alarms and control.

12.2.2 DC Feeder System

The DC feeder system includes the positive DC feeders from the traction power substation to the overhead contact system, the negative DC feeders from the substation to the rails, and any parallel underground feeders required to locally reinforce the overhead contact system's electrical capacity.

12.2.3 Overhead Contact System (OCS)

The overhead contact system consists of all equipment between and including the positive DC feeder interface and the overhead contact wire. This equipment includes the supporting structures, guys, foundations, conductors, overhead feeders, ancillary wires, hangers, insulators, conductor supports, hardware, jumpers, tensioning devices, sectionalization equipment, disconnect switches, lightning arresters, and parallel feeders.

12.2.4 Signal and Communication Power Supply System

The traction power substations may also supply power to signal bungalows. The interface point between the traction power substation and the signal and communication system is the termination point of the power supply cable at each signal bungalow.

12.2.5 Sectionalization

The DC power distribution shall be double end feed type, where electrical continuity between adjacent substations is provided by the overhead contact system

The two mainline tracks, the inbound and outbound, shall be electrically parallel.

Insulated overlaps and section insulators in the overhead contact system shall be used to allow power to be isolated from track zones. Section insulators shall only be used in slow speed situations such as crossovers.”

Disconnect switches shall be installed at overhead contact system feeding points, overlaps, crossovers, and across selected sectioning locations in the mainline to provide flexibility in operations.

The traction power supply to the yard, maintenance shops, and mainline shall be electrically separated. The negative return system in the shop shall be solidly grounded to the shop building and shop grounding system. The negative return for the yard tracks shall not be grounded during normal operations but provisions shall be provided by means of a grounding switch to automatically ground the return rails should the rails reach an unsafe level of voltage. The return rails for the mainline shall be electrically insulated from earth and meet the minimum resistance-to-earth criteria as defined in the Corrosion Control Criteria for stray current protection (see Chapter 16).

Provision shall be provided for emergency interconnection of the yard traction power supply to the mainline and shop traction power supply systems. Insulated rail joints shall be installed at the entrance to the yard facility and section insulators shall be installed in the OCS to prevent any unintended connection between the traction power system for the shops and that for the yard and mainline.

12.2.6 Design Environment

The traction power system shall be designed to operate satisfactorily in the environment as described in Section 1.3.9, “Weather Conditions for Systems Design.”

12.2.7 Codes and Standards

All materials, apparatus and equipment, installation methods, and testing shall conform to or exceed the requirements of the applicable portions of the latest edition of ANSI, NEMA, NEC, IEEE, UL, IBC, ICEA, EIA, ASTM, UDOT, and AREMA. Other local and state codes may also apply. The system shall be designed in compliance with industry standards, and the most stringent of these codes.

12.3 Traction Power Substations

12.3.1 General

Direct-current (DC) traction power shall be provided by traction power substations with rated voltage output of 750 Vdc at 100% load. Maximum voltage output (at rated AC input voltage) below 1% full load at the substation bus shall not exceed 795 Vdc. Rectifier-inherent voltage regulation shall be maximum 6%, linear from 1% full load to 100% load and as linear as technically feasible from 100% load to 450% load.

The overhead contact system, running rails, and associated connections shall be capable of maintaining a voltage at the LRV no lower than 525 V.

12.3.2 System Operating Requirements

The following shall constitute the basis for electric traction power system design and rating:

- Nominal contact wire voltage 750 Vdc
- Maximum contact wire voltage 900 Vdc
- Vehicle operating voltage (min.) 525 Vdc
- Maximum rail to ground voltage 50 Vdc

The vehicles are equipped with regenerative braking. The system shall be designed for natural reception only. No power shall be fed back to the utility.

12.3.3 Basis for Substation Location, Spacing, and Rating

The traction power substation (TPSS) shall be located, whenever practical, at or near passenger stations. These locations shall be optimized with respect to system safety, system efficiency, right-of-way availability, system availability, stray current control, minimum life cycle cost, and interconnection to the utility network.

12.3.3.1 Normal Operation

The spacing and rating of the TPSS shall be designed so that adequate power shall be supplied to the system, with all substations operating, to maintain rated train operating performance during peak-hour LRT operating conditions with 4-car trains at 10-minute headways in both directions at AW2 loading. This shall include simultaneous starting of two 4-car trains at any passenger station.

12.3.3.2 Contingency Operation

With any one TPSS out-of-service, one 4-car train at AW4 loading shall be capable of starting and accelerating at rated train operating performance as if the system was operating normally. Two trains, however, shall be able to start simultaneously at the outage but they may accelerate and perform at a reduced operating level.

12.3.4 Substation Power Supply

The electric utility company shall provide to each traction power substation 3-phase, 60 Hz power circuits as primary service. The present standard service voltage in the Salt Lake Valley is 12.47 kV. The evaluation shall determine the most cost-effective investment and lowest annual operating cost that shall provide adequate and reliable service to the LRT system.

Normally a single electric utility company feeder shall supply no more than two electric traction substations. These two substations shall not be adjacent. If unavoidable, utility feeders supplying adjacent substations shall be independent and as a minimum emanate from different buses. Under emergency conditions (one utility company substation out), a single feed shall supply no more than three electric traction substations. Emergency feed conditions (three TPSS maximum per AC feeder) may result in reduction in train performance.

12.3.5 Substation Equipment

The basis for transformer/rectifier rating shall be the extra heavy duty cycle defined as follows: after reaching a steady state temperature, the rectifier transformer shall run at 150% of its rated load for 2 hours. During this 2-hour period, 5 equally spaced 300% loads shall be imposed on the unit for an 1-minute duration each. At the end of the 2-hour cycle, a 450% load shall be imposed for 15 seconds. At the end of this duty cycle, there shall be no damage to the rectifier/transformer or any of its components. All components shall comply with NEMA requirements.

All substations shall have one transformer/rectifier unit.

Substations shall be prefabricated units equipped with high-voltage AC switchgear (incoming circuit breaker), surge arresters, transformer/rectifier units, and DC power switchgear and shall be designed to operate unattended. Controls shall be provided to operate all switchgear remotely and from local control switches in the equipment. The transformer/rectifier units shall be connected in accordance with ANSI Standard C34.2; mainline and yard units shall deliver a 12-pulse, double-way output.

Rectifier transformers shall be self-ventilated dry type Class AA, suitable for indoor service. Silicon diode rectifiers shall be free-standing indoor type metal enclosed, natural convection air-cooled. The transformer/rectifier units shall be rated extra-heavy traction rating class, in accordance with the above defined extra heavy-duty cycle. The harmonic characteristics shall comply with utility requirements and IEEE Standard 519.

The feeder breakers shall be indoor, metal enclosed, drawout, 800 Vdc rated (950 Vdc maximum), single-pole, high-speed capable of interrupting the maximum short-circuit current available. A bolted link shall be provided to disconnect the rectifier from the DC positive bus. Auxiliary equipment shall include lightning or surge protection, interconnecting buswork, 125 Vdc control-power battery and charger/eliminator, and space for the provision of stray-current monitoring cabinets. For stray current corrosion control data see Chapter 16.

Circuit breakers shall be installed to provide isolation of track sections.

Circuit breakers shall be equipped with direct acting instantaneous overcurrent rate-of-rise, multi-stage time overcurrent, and automatic reclosure relaying, and direct transfer trip between substations. The protection shall open all breakers feeding a faulted section. At the substation, circuit breakers shall be used for all feeders. After two trips a manual reset shall be required.

Circuit breakers shall normally be operated by local controls under manual operation within each substation. Provisions shall be made for remote control and supervision.

Each utility feeder line shall be provided with revenue metering in accordance with the requirements of the electric utility.

Indicating meters shall be provided to display the following:

- AC line current
- AC bus voltage
- DC positive bus voltage
- DC feeder line current
- DC feeder voltage
- DC negative bus voltage (mainline substations and yard negative bus)
- DC leakage current (shop negative bus)
- Facilities for future connection of drainage cables and stray current measurement

12.3.6 Substation Enclosure

All traction power substations shall be designed to meet basic safety and fire protection requirements. Traction power substations shall be considered as Group B, Division 4 occupancies when referencing the International Building Code¹ for occupancy related requirements.

The basic requirements to be incorporated into the building design shall include the following:

- Emergency access to and egress from the substations shall be in accordance with local fire codes and the Uniform Building Code.
- Emergency lighting and exit signs shall be in accordance with local codes, the Uniform Building Code, and Fixed Guideway Transit Systems².
- Substations shall be provided with an automatic fire detection system and portable fire extinguishers. They shall comply with Chapter 38 of the Uniform Building Code and local code.
- Substation doors shall be monitored by a security system. Entry by unauthorized persons shall be prevented by means of locks and special keys. Wayside electrical control equipment and switches shall be secured by key locks.

12.3.7 Substation Foundation

The design of the substation foundation shall conform to established civil and structural engineering practices, American Society for Testing Materials (ASTM) and American Concrete Institute (ACI) standards, and other applicable and local codes. The substation foundation shall be structurally capable of withstanding the live and dead loads of the substation equipment occurring during installation, operation, and maintenance of the substation.

12.3.8 Substation Grounding

As a principal goal, the traction power system shall be designed to provide safety both to personnel and to the overall system. The design of the grounding system shall preclude any unsafe condition to either system personnel, patrons or the community. Each substation shall be equipped with a $2 \times \frac{1}{4}$ " copper ground bus and necessary cabling to a substation grounding grid.

Noncurrent-carrying metal enclosures or parts of alternating current equipment, including AC apparatus and rectifier-transformers, shall be securely connected to the ground grid.

¹*International Building Code*. Country Club Hills, IL: International Code Council, Inc., current edition.

²*Fixed Guideway Transit Systems* (NFPA 130). Quincy, Massachusetts: National Fire Protection Association, 1997.

Enclosures for traction power rectifiers, DC switchgear, and DC busways shall be installed insulated from ground, and each shall be connected to the substation ground grid through a low resistance ground fault detection system. The ground fault detection system shall detect enclosure hot as well as enclosure ground conditions.

The main negative bus of each traction power substation shall be connected to the return negative bus through a shunt for current measurement purposes.

Ground connections to disconnect switches and ground leads on all surge arresters shall have a maximum ground resistance of 5 ohms. Ground rods can be connected to a grounding system which shall be utilized to obtain the required ground resistance.

The DC system shall normally be operated ungrounded. The traction power rectifier/transformer output (DC) windings shall be isolated from ground.

The ground grids, consisting of driven ground rods and conductor mats embedded in the earth, shall be designed for safe step-and-touch potentials *DRV IEEE 80*. These grid materials shall be resistant to corrosion by the earth's chemistry.

The incoming feeder ground and the facility ground should be connected to separate systems.

Maximum step and touch voltage shall not exceed the allowable values defined in IEEE Standards for AC systems.

12.3.9 Ventilation

The substations shall include an air conditioning system to maintain the substation temperature at a level permitting the traction transformers and the rectifiers to operate at their design load cycle. A minimum of two fans shall be furnished for each substation; each shall be rated at 75% of the total substation requirement.

12.3.10 Noise Level

The substation sound level shall be limited to the levels specified in Chapter 2.

12.3.11 Miscellaneous

12.3.11.1 Interior Lighting

Indoor lighting shall be provided by fluorescent fixtures. The design shall provide for minimum maintained lighting levels of 30 foot candles vertical, average.

Lighting shall illuminate the vertical surfaces of the equipment, such as switchgear and transformer/rectifier units, and shall be located so as not to create a glare on the front of the devices or meters. Locations of lighting fixtures shall be coordinated to avoid interference with overhead raceways or other major wiring and shall not be directly above switchgear, rectifiers, or transformers.

Outdoor lighting shall be provided by sodium lamp fixtures with unit photo cell control. Design shall provide a minimum illumination level of 2 foot candles at ground level. The general lighting shall be controlled from switches located near each access door.

12.3.11.2 Emergency Lighting

Substations shall be provided with emergency lighting consisting of rechargeable nickel-cadmium batteries and battery chargers, with one or more lamps mounted on the equipment and a relaying device arranged to energize the lamps automatically on failure of the AC power. The battery charger shall have the capacity to supply rated load for 1.5 hours at not less than 87.5% nominal battery voltage.

Sufficient fixtures shall be provided to illuminate the area as required by code(s).

12.3.11.3 Convenience Outlets

Two duplex convenience outlets shall be conveniently located around the interior walls of the substation. One 20-Amp duplex outlet near the switchgear and rectifier shall be separately circuited to permit use of a heavy-duty vacuum cleaner or up to ½-horsepower portable air compressor. One weatherproof duplex outlet located on an exterior wall of the substation shall be provided with outlet covers and tamper proof screws.

12.3.11.4 Intrusion and Fire Alarm System

A smoke detector device shall be provided within the substation with provisions for local annunciation and remote indication.

An electro-mechanical intrusion detection device on each entry door shall be provided with provisions for local annunciation and remote indication.

12.3.11.5 Safety and Maintenance Equipment

An emergency eye-wash unit shall be provided, suitably located inside each substation enclosure.

Two portable fire extinguishers shall be provided in each substation enclosure.

Separate test cabinets shall be provided for the testing of withdrawable AC and DC circuit breakers in each of the substations.

12.3.11.6 Auxiliary Power

The power for station services (240/120 Vac) in and about the substations shall be provided. These loads include, but are not limited to lighting, battery charger, and climate control.

12.3.11.7 Uninterrupted Power System

Maintenance free batteries and a battery charger shall be used as a backup power source for the essential protection devices and substation equipment control for up to 8 hours in the event of a utility power failure.

12.3.11.8 Working Space

Working space shall be provided within the enclosure to permit movement of major pieces of equipment and performance of maintenance functions.

12.4 DC Feeder System

12.4.1 General

The DC feeder system shall consist of cables and raceways designed to supply power from the substation to the OCS and rails. Feeder cables shall be insulated, conform to ICEA standards and specifications, and be suitable for both wet and dry locations. The raceway shall be underground and the design of the ductwork, the embedment depth, and the manhole spacing shall be in accordance with the NEC requirements.

At their points of entry the DC switch gear and at the point where the positive feeders top to the OCS, underground feeders shall be protected against lightning strikes.

Conduits, ducts, manholes, and cableways shall be provided for the AC supply cables from the traction power substation to the interface point with the utility, for the positive DC feeder cables from the substation to the interface with the OCS, and for the negative DC feeder cables from the substation to the running rails. The cableway requirements shall be coordinated with UTA and with the utility.

The basic requirements to be incorporated into the design of raceways and cables shall include the following:

- All material manufactured for use as conduits, raceways, ducts, boxes, cabinets, equipment enclosures, and their surface finish material shall be suitable to withstand temperatures of 932 °F (500 °C) for 1 hour, and shall not support combustion under the same temperature condition.
- All conductors except those specifically excluded by UTA Light Rail Project Director shall be insulated. Minimum thickness of insulation and jacket shall conform to the ICEA and National Electric Code®³ for the voltage and use intended.
- All insulation shall conform to Article 310 of the National Electric Code® and be moisture and heat resistant types carrying temperature ratings corresponding to the conditions of application. Only insulation materials designed for temperature ratings higher than 194 °F (90 °C) shall be used.
- All cables in open raceways and in underground areas shall pass the flammability requirements of Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations⁴ and the smoke emission requirements of Smoke Generation of Solid Materials⁵.

12.4.2 Cables

Feeder conductors shall be insulated, non-shielded, single conductors suitable for use in wet or dry locations and rated 2,000 Vdc, 90 °C conductor temperature for normal operation, 130 °C for emergency operation, and 250 °C for short-circuit conditions. The conductors shall be copper, conforming to ASTM B189 material with class C or D stranding, conforming to ASTM B8, with EPR insulation and low smoke jacket.

³*National Electric Code®* (NFPA 70). Quincy, Massachusetts: National Fire Protection Association, 1993.

⁴*Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations* (IEEE 383). Washington, D.C.: Institute of Electrical and Electronics Engineers, Inc.,

⁵*Smoke Generation of Solid Materials* (NFPA 238). Quincy, Massachusetts: National Fire Protection Association,

Traction power cables connecting DC feeder breakers to the overhead contact system, and from running rails to the negative bus, shall be sized to accept maximum overload and short-circuit currents with a temperature rise not to exceed safe design limits of the cables.

Feeders shall be standardized on a single-conductor size by using multiple conductors for different amperages. The cables shall have sufficient conductivity to maintain traction power voltage levels at the required level. Traction power feeder cables shall be sized to operate at rated insulation temperature during normal operating conditions.

At points of entry and exit of underground feeders, protection against lightning strikes shall be provided.

The positive and negative traction power cables, where installed in exposed locations, shall be adequately supported on insulated racks or trays and can be so located as to minimize the possibility of incurring physical damage. Flame-resistant jacketed cables shall be used in such installations.

The DC feeder cables from the substation to the OCS shall not be spliced. Parallel underground DC feeder cable splices shall be allowed in manholes when necessary.

12.4.3 Raceways

Feeder ductwork shall be buried underground and shall consist of conduit encased in concrete. Design of ductwork such as conduit size, design cable pull, maximum total angular turn, minimum embedment depth below grade, manhole spacing, and duct gradient shall be in accordance with NEC requirements. Feeder ductwork shall be identified by a yellow warning tape 6 inches wide marked “Warning—High Voltage,” laid 12 inches above concrete encasement in backfill.

Feeder ductwork shall be run as directly as practicable and shall be located to avoid interference with foundations, piping, and other similar underground work. Risers consisting of conduit shall be provided at feeder connections to the OCS.

Manholes and pull boxes shall be located to facilitate installation of the cables. The use of pull boxes is preferred and the selection of a manhole or a pull box shall be done on a site-specific basis. Number of ducts to be installed shall have 20% spare capacity or a minimum of two spares to permit additional cables to be pulled for non-tubular poles.

12.5 Overhead Contact System

12.5.1 General

The overhead contact system (OCS) includes the overhead conductor system and the associated physical support system.

The OCS consists of the conductors, including the contact wire and supporting messenger wire, in-span fittings, insulation, jumpers, conductor terminations, and associated hardware located over the track and from which the vehicle draws power by means of direct physical contact between the pantograph and contact wire. The OCS shall provide for proper current collection under all operating conditions.

The physical support system consists of foundations, poles, guys, insulators, brackets, cantilevers, and other assemblies and components required to support the OCS in the appropriate overhead configuration. The support system shall support the OCS in accordance with allowable loading, deflection, and clearance requirements. The OCS supports throughout the system shall incorporate double insulation.

The DC feeder system consists of the feeder conductors, jumpers, switches, ductwork, and associated hardware that feed the power to the OCS. The feeder system, in combination with the OCS, shall provide for the supply of traction power from the substations to the vehicles within the allowable voltage limits.

The OCS shall be electrically continuous from substation to substation. At the substations, the OCS and underground parallel feeders shall be sectionalized to provide isolation of each electrical section. An arrangement providing continuity and flexibility for sectionalization of the OCS, while any substation is undergoing repair or maintenance, shall be incorporated. This shall be accomplished through the application of disconnect switches.

In addition to sectionalizing at the substations, the OCS shall be sectionalized at crossover s or other special trackwork locations, and in the yard, to provide for flexibility in LRT operations and maintenance.

Jumper cables shall be provided to maintain electrical continuity at special trackwork locations where it is necessary to have a physical separation in the OCS . At locations where jumper cables are used to provide full-feeding electrical continuity, they shall be equal to or greater than the electrical capacity of the OCS circuit ampacity.

The OCS shall allow train consists to operate utilizing one to four pantographs without causing excessive oscillation in the overhead contact system or pantograph bouncing. The overhead contact system shall be designed according to the current AREMA⁶ recommendations. Pantograph clearance from the OCS support system shall be maintained at all times.

The design of the OCS shall be based on technical, economical, operational, and maintenance requirements as well as on the local climatic conditions which are outlined in these criteria.

In order to maintain the pantograph head on the contact wire, the design factors to be considered, but not limited to, shall include OCS conductor blow-off, contact wire deviation due to movement of hinged cantilevers, mast deflection due to imposed operational loads, vehicle roll and lateral displacement, width and sway of pantograph, track maintenance tolerances, OCS erection tolerances, and incorporate a pantograph security factor.

12.5.2 OCS Configuration

A simple catenary auto-tensioned system (SCAT) consisting of a messenger wire supporting a contact wire by means of hangers, shall be used for the mainline at-grade railroad right-of-way and on elevated guideway. The conductors shall be tensioned by means of balance weights. The catenary system shall be supported by hinged cantilevers attached to wide flange galvanized or tubular steel poles located between the tracks whenever possible. If necessary, at special locations such as track crossovers, turnouts, curves, and junctions, poles may be located on the outside of the track. A headspan configuration may be used in multi-track areas if single poles cannot be installed. A single wire fixed termination (SWFT) consisting of a contact wire supported by means of fixed terminations shall be used in yards, shops, and at tight track curves or complex major intersections. This configuration is utilized where auto-tensioned OCS interfaces with tight track curves and/or complex major intersections (with multiple track moves). Such onerous track geometry complicates the use of auto-tensioned catenary instead. Due to electrical demands, underground parallel feeders are installed and connected to the contact wire to supplement the OCS capacity. The contact wire in the yard shall be supported by means of single or back-to-back

⁶American Railway Engineering and Maintenance of Way Assoc.

pole-mounted cantilevers, bracket arms, cross-spans, and headspans. In the shop, the system shall be suspended from the building structure.

The OCS configuration along an alignment shall be determined by mutual agreement between UTA and the stakeholders in each area of the project.

Underground parallel feeders connected to the OCS shall be utilized to satisfy the electrical load requirements of the traction power supply system.

12.5.3 Operations

The OCS shall be designed for LRT vehicle operations with track specified in Chapter 4 and vehicles specified in Chapter 11.

The OCS shall be designed for multiple pantograph operation with pantographs spaced in accordance with the specified train consists.

12.5.4 Contact Wire Height

The contact wire height for various alignment segments shall be in accordance with the National Electric Safety Code (NESC) or local requirements as follows:

<u>Alignment Type</u>	<u>Wire Height Above Rail Minimum</u>
Segregated right-of-way (without railroad)	See Section 3.7.4
Mixed-used, pedestrian only (restricted vehicles)	16'-0"
Mixed-use with road vehicles	18'-0"
Mixed-use with railroad	22'-6"

These values are provided for the worst combination of tension, sag, temperature, construction and maintenance tolerances, and applicable electrical clearances. These dimensions should be reviewed in conjunction with table in Section 3.7.4.

Maximum contact wire gradients shall, wherever possible, not be more than 1 in 4 times line speed, and changes in gradient should not exceed half this value. The contact wire height at supports shall take into consideration the effect of wire sag, due either to temperature rise or to ice loading, and installation tolerance (including track construction and maintenance tolerances).

At critical locations (restricted clearance under bridges) or fixed track work points (e.g., grade crossings, and embedded or direct fixation track work), no allowance shall be made in the OCS design for track lift. At non-critical locations, the OCS design shall allow for a future track lift of up to 3 inches.

When changing from one OCS type to another, the contact wire height shall be changed gradually to prevent pantograph bounce and arcing. The maximum gradients for contact wire change in elevation relative to the track elevation, shall be in accordance with the AREMA Chapter 33 as follows:

<u>Speed Limit/Location</u>	<u>Maximum Gradient</u>
Yard	2.3%
30 mph	1.3%

45 mph	0.8%
55 mph	0.7%
60 mph	0.6%

Except for the yard, the change of grade from one span to the next shall not exceed one half of the value shown.

12.5.5 Vehicle Data

See Chapter 11.

12.5.6 Climate Conditions

The OCS design shall be based on the National Electric Safety Code and the climatic parameters described in Section 1.3.9, “Weather Conditions Criteria for Systems Design.” Wind velocity of 4 ft/sec will be used instead of 2 ft/sec when calculating ampacity for OCS system.

12.5.7 Loading

Loading shall be based on NESC Rule 250-B, combined wind and ice loading, heavy loading district:

- 4 lb/ft² horizontal wind pressure
- ½ in. radial ice on conductors
- 0.3 lb/ft constant added to the resultant
- 0 °F (–18 °C) temperature

12.5.8 Span Lengths and Stagers

The contact wire shall be staggered on both tangent and curved track. Stagger is the deliberate lateral displacement of the contact wire at each support to the left or right of the perpendicular track centerline. On tangent track, the wire is staggered primarily to achieve uniform wear of the pantograph carbon collector strip. On curved track, the stagger achieves the tangent/chord construction necessary for the “straight-wire” OCS to negotiate the curve.

The span lengths (spacing between messenger wire or single contact wire support points) and stagers shall be designed to provide for pantograph security (i.e., no pantograph dewirement) and to maintain good current collection and uniform wear of the pantograph carbon collector. Pantograph security is established by maintaining a minimum contact wire edge distance (from the horn of the pantograph) of 4 inches under worst operating condition.

The design shall consider the effects of environment, track geometry, vehicle and pantograph sway, and installation and maintenance tolerances. Vehicle roll into the wind shall be taken equal to 50% of the maximum dynamic roll value, in accordance with AREMA Manual, Chapter 33, Part 4. To minimize the possibility of harmonic oscillation in the OCS, not more than five equal spans shall be located successively. A span which is at least 10% shorter shall be inserted to minimize the possibility of any sympathetic oscillation.

12.5.9 OCS Conductors

The contact wire shall be solid grooved hard-drawn copper, conforming to ASTM Specification B47 (size: 350 MCM).

The messenger wire shall be standard hard-drawn copper, conforming to ASTM Specification B189, (size: 500 MCM), with stranding conforming to ASTM Specification B8, class B or higher.

In the design for conductor tension, the following shall be considered:

- 30% cross-sectional area loss due to wear of contact wire
- the effect of temperature change on all conductors
- NESC

12.5.10 Construction and Maintenance Tolerance

The purpose of the OCS is to provide electrical power to the LRV, via the pantograph collector. Consequently, it is vitally important that the contact wire is installed correctly above the as-built track work. Construction tolerances shall be:

- Contact wire height (CWH) shall be 0" to +3" at all locations, subject to gradient criteria.
- In general the messenger wire is to be installed above and vertically in line with the contact wire. Allowable tolerances are given below. Messenger wire stagger (relative to contact wire):
system heights up to 1'-6" = ½"
system heights 3'-0" = 3"

Maintenance tolerances shall be developed during final design.

12.5.11 Poles and Foundation

The OCS conductors shall be designed in accordance with the factors outlined in the NESC under the loading conditions specified.

12.5.12 Poles and Foundation

Outside of a street-running environment, poles shall be wide flange galvanized steel with steel base plates. Within street-running environments, the poles shall be tubular and support single contact wire or low-profile catenary. "H" piles with shrouds or equivalent shall be used for balance weight poles. The pole finish shall be in accordance with UTA's final recommendation. All poles, except those on selected structures, shall be installed on cast-in-place reinforced concrete foundations by means of embedded anchor bolts. On the structures the poles shall be supported by means of anchor bolts installed through the deck or cast into piers. Poles shall be grounded by a bonding cable attached to a grounding plate which shall be installed as part of the foundation installation. The pole grounding plate, foundation bolts, and reinforcing bars shall be electrically connected. Poles shall be sized in accordance with NESC Rule 260. In particular, the following overload factors shall be applied to the calculated loads:

<u>Load Type</u>	<u>Overload Factor</u>
Gravity	1.50
Ice	1.50
Wire (radial)	1.65
Wind	2.50

In addition to the NESC heavy loading and load factor requirements, the poles shall be designed to withstand the following combined loads with the overload factors shown applied to the calculated loads:

<u>Load Type</u>	<u>Overload Factor</u>
Gravity with ice	1.50
Wire tension at angles	1.65
21 lb/ft ² horizontal wind	1.00

This set of conditions is similar to NESC Rule 261-A.1.a and 250-C except that the conductor loads are also included in this case.

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

The pole deflection due to live loads plus foundation rotation during train operation shall be no more than 2 inches at contact wire height. Pole deflection at the top of the pole under NESC heavy loading condition excluding live loads shall be no more than 3% of pole length. Poles shall be raked back to compensate for static loads. Overload factors shall not be applied in the calculation of pole deflection.

Foundation design shall be coordinated with the track designers. The design and construction of the pole foundation and guy anchor foundations shall conform to established civil and structural engineering practices, ASTM and ACI standards, and other applicable codes. The foundations shall be reinforced concrete and shall be capable of withstanding the design load imposed during installation, operation and maintenance. Foundations shall be designed to limit the total effect of foundation rotation and pole deflection during train operating conditions to 2 inches at the contact wire level.

Guy foundations should be set in line with the restrained conductor to avoid bending stress in the pole due to conductor tension.

12.5.13 Electrical Clearances

The following clearances shall be maintained between live conductors (including pantograph) and any grounded fixed structures in accordance with the AREMA Manual, Chapter 33, Part 2, as follows:

	<u>Static</u>	<u>Passing</u>
Normal Minimum	4"	3"
Absolute Minimum	3"	3"

Static clearance is the clearance between the OCS, when not subject to pantograph pressure, and any grounded structure.

Passing clearance is the clearance between the OCS or pantograph and an overhead structure under actual operating conditions, during the time it takes the train to pass.

Mechanical clearance from the pantograph to any fixed item, excluding the steady arm or registration pipe of the cantilever, shall not be less than 3 inches. Clearance to steady arms and registration pipes shall not be less than 1½ inches.

For vehicle-related clearances (see Chapters 3 and 11), full allowance shall be included for dynamic displacement of the vehicle under operating conditions (including track and other installation and maintenance tolerances).

12.5.14 OCS Support Systems

Various OCS support systems are required to suit the different styles of OCS and applications. They shall be double insulated to limit leakage currents, and to permit “live-line” maintenance operations.

12.5.14.1 Cantilevers

The general type of support shall be the single-track cantilever, or center pole, back-to-back cantilever brackets. The mast attachments shall be fitted with hinge pins to permit along track movement of the OCS conductors due to temperature change.

12.5.14.2 Headspans

Multi-track supports shall be required at some locations, typically passenger stations and crossovers. To minimize overhead clutter, 3-wire headspan support arrangements shall be used in preference to portal structures. The support assemblies shall permit along track movement of the conductors.

12.5.14.3 Cross-spans

In the downtown intersection areas and in the yard, simpler support arrangements for either multi-track situations or for crossing the intersection shall be required. Simple 1- or 2-wire cross-spans shall be utilized.

12.5.15 Bridge Attachments

Attachments may be required at certain overhead and undergrade bridges. Provisions shall be made for the proper grounding of underbridge attachments.

12.5.15.1 Overhead Bridges

Wherever practicable, attachments shall not be made to overhead bridges. Where clearance limitations or along-track length of the bridge make attachment a necessity, the number shall be limited. To minimize pantograph bounce, and loss of contact between the pantograph and contact wire, a soft resilient type suspension assembly shall be used.

12.5.15.2 Undergrade Bridges

Supports shall not be located on undergrade bridges, except in situations where the bridge span is greater than the allowable OCS span.

12.5.16 Disconnect Switches

Disconnect switches shall be equipped with provisions for padlocking, and shall be interlocked to prevent unauthorized operation.

Pad-mounted switches shall be used wherever possible except where operations do not allow it.

12.5.17 OCS Tensioning

Auto-tensioned equipment shall use balance weights. Balance weights shall be cast iron, lead, or steel. In area of public access, the balance weights shall be suitably contained to mitigate tampering.

12.5.18 OCS Grounding and Bonding

The OCS shall be properly grounded in accordance with NEC requirements. Generally, footing resistance of individual structures shall be maintained at a maximum of 25 ohms. A ground stud shall be provided on the baseplate of each pole, to which a ground jumper shall be bolted. This jumper shall be welded to the foundation reinforcement cage. If necessary, additional ground rods shall be installed to achieve the minimum grounding resistance. Connection to the pole shall be made using the grounding stud.

12.6 Negative Return Path and Stray Current Control

The rails shall be welded in continuous lengths and bolted joints shall be electrically bonded. At locations requiring insulated joints, the traction power direct current continuity of negative rails shall be maintained by use of impedance bonds. In areas of double track equipped with vital double-rail AC track circuits, cross bonding between tracks for negative-traction, current-return equalization shall be accomplished by impedance-bond center-tap connections at each substation return feeder location. In no instance shall consecutive impedance bonds be used for either cross-bonding or substation return connections. In areas of trackage not equipped with track circuits, cross-bonding between tracks shall be accomplished by direct connections to both running rails. Impedance bonds shall be located outside of the rails adjacent to the track.

To minimize stray currents and to provide a means of monitoring such currents in the affected structures and utilities in the proximity of LRT facilities, the following provision shall be made:

- The mainline traction power system shall be isolated from the LRT yard
- Rails shall be insulated from direct contact with ground by means of insulated pads and spikes
- Cross bonds shall be installed between rails at appropriate locations
- Test stations shall be established so that measurements can be taken where deemed necessary
- Electrical continuity between pole structure and foundation shall be maintained.

The mitigation measures listed above shall be coordinated with Chapter 16.

12.7 Interfaces

The traction electrification design shall be fully coordinated and interfaced with the affected utilities, railroads, agencies, and other designs on this project. The major interface areas include:

- Track alignment
- Track work configuration
- Utilities
- Structures
- Vehicles
- Operations
- Electrical and mechanical equipment
- Signaling, communications, and train control center
- Yards and shops
- Architectural

- Corrosion control
- Passenger stations
- Real estate
- Noise and vibration

END OF CHAPTER 12.



Utah Transit Authority Light Rail Design Criteria

Chapter 13 Signal System

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 20060
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 13 SIGNAL SYSTEM

13.1 General

This chapter describes the functional design requirements, the interface criteria with other work, and the selected hardware technologies for the LRT signal system.

13.1.1 *Signal System Description*

13.1.1.1 General Description

Light rail shall operate in dedicated right-of-way or share the street with existing traffic. In dedicated corridors, LRT and freight vehicles may use the same track but shall be time separated. Therefore, the signal system in the joint-use sections must be designed to accommodate two separate types of vehicles, operating speeds, and conditions. The dedicated portions of right-of-way shall use conventional fixed-color light signals for train separation and safe braking distance. Where the track will share existing streets with automobiles and where railroad-type signals will not be provided, LRV traffic signals shall govern.

The signal system shall use off-the-shelf, standard material and components to the greatest extent possible to provide the lowest cost and highest levels of reliability, maintainability, and safety performance for both rail and street traffic. It shall be based on an automatic block system compatible with freight operations, radio communication and traction electrification systems, transit vehicles, and the EMI environment. All track segments in dedicated corridors shall be designated and signaled for single-directional running with expansion capabilities for bi-directional running.

Reverse running shall be under manual block signaling between interlockings but controlled by the home signal. That is, in double track sections a route can be selected in the reverse direction from a home signal. The home signal will perform a block check to the next home signal and display a “proceed only as directed by the Dispatcher” aspect. Automatic signals will only be used for normal direction traveling.

All single track segments shall be signaled for double direction running. Single track areas shall be designed to accommodate future upgrading to double track operation. The signal system shall accommodate the track configuration to service both freight and light rail needs.

13.1.1.2 Signal System Feature Highlights

Impedance bonds shall be installed at block boundaries as required to provide propulsion return continuity. Impedance bonds shall have 1,500 amp capacity and be tuned or provided sufficient impedance at 60, 100, 156 hertz to be compatible with signal train detection circuits and coded track system. Signal logic and control shall be transmitted via the rails and/or over wayside cables. Normal routes through interlockings shall be aligned and cleared automatically or manually via supervisory control, local control, or wayside pushbutton. Non-revenue routes, normal switching moves, and turnbacks shall be selected from wayside, pedestal-mounted pushbuttons with supervisory direction only. Provisions for future supervisory and train to wayside communications shall be provided.

Switch machines at terminal ends and mainline crossovers shall be controlled by either electric power or hand thrown lever, with electric and mechanical locks as appropriate.

Switch-machines at turnouts to freight sidings and branch lines shall be hand-operated and equipped with controlled electric locks when required per FRA part 236, and point detector protection.

Spring switches shall be equipped with point detection and circuit controllers to detect their position.

13.1.2 General Design Requirements

13.1.2.1 Safety and Systems Assurance

During the design and installation of the signal system, a Systems Assurance Program shall be employed to meet the goals of system safety. Scientific and engineering principles shall be applied to identify and analyze potential hazards and to eliminate, control, or minimize the hazards.

The signaling system shall be designed to be fail safe; that is, any malfunction affecting safety shall cause the system to revert to a state known to be safe.

13.1.2.2 Electromagnetic Compatibility

The signal system shall be designed to operate in the electromagnetic environment of the UTA system, while causing the minimum possible interference to other systems. The equipment shall be designed, selected, and installed with consideration given to the electromagnetic environment, which includes the traction power supply, ac power distribution systems, vehicle propulsion systems, communication systems, adjacent railroads, industrial facilities, and electric utility lines. Prior to implementation of electronic or coded track circuits, the contractor shall perform an online demonstration to ensure compatibility with UTA's vehicles. The contractor shall perform a detailed analysis of the train detection system as it relates to vehicle EMI compatibility and provide the analysis to UTA for approval.

13.1.2.3 Circuit Design

Vital interlocking circuits shall be designed using standard signaling techniques. Line circuits, where used, shall be double wire, double break. Vital circuits shall utilize vital relays or vital microprocessor interlockings per recommendations of the AREMA Signal Manual.

Non-vital circuits shall utilize non-vital relay or solid state technology. Failures of non-vital equipment shall not affect the safety of the system.

13.2 Interface Requirements

The signal system shall be designed in such a way that it shall be fully interfaced and compatible with other existing UTA and city traffic controller systems. The basic interfaces identified are vehicles, traction power, traffic control and LRT signal priority system, tracks, and catenary structures and civil work.

13.2.1 Vehicles

Track circuits shall be compatible with EMI generated by the UTA vehicle and other factors found in Section 13.1.2.2, including future wayside control technology.

UTA vehicle parameters and performance characteristics shall be used to develop safe braking distance and signal block design.

13.2.2 Traction Power

The signal system shall be compatible with EMI generated by the traction electrification system and other factors in Section 13.1.2.2.

Impedance bonds shall be installed at negative return, signal cut sections and cross bonding locations. Cross bonding shall be coordinated between signal and traction power final designers to assure that adequate cross bonds are provided for traction power return without compromising track circuit and coded track integrity. In street-running operation where train detection circuits are necessary, single rail track circuits are used.

13.2.3 Traffic Control and LRT Signal Priority System

The objective of the Traffic Control and LRT Signal Priority System is to provide for LRV progression while maintaining an appropriate balance for cross-street traffic. This system involves the intersection traffic signal controller, LRT priority system, LRT detection system, LRT signals, and traffic/LRT signal timing plans. In some areas, the LRT priority function will be handled by the intersection traffic controller alone. In selected areas, the traffic signal controllers will also be integrated into the UDOT/SLC Advanced Traffic Management System (ATMS) which provides centralized LRT/traffic management.

The railway signal system shall interface with intersection traffic signal controllers in cases where signal preemption is required at grade crossings and in special cases where interface is required between crossover interlockings and the traffic controller.

13.2.4 Catenary Structures

Catenary structure clearance requirements shall be incorporated into highway crossing protection designs. Signal sites shall be selected so as to avoid interference with catenary structures. Coordination during design will be required between appropriate designers.

13.2.5 Civil Work

Wayside signal equipment installation shall depend on civil constraints such as right-of-way limits, visual obstructions, highway crossing physical dimensions, and track clearances.

Track grade and curvature effects and other civil restrictions shall be incorporated into the signal block design.

Setbacks for bungalows from centerline of track shall be 8'-6" minimum to closest face of bungalow per Utah State General Order 66.

13.3 Site Work

13.3.1 Concrete

Signal equipment houses, cases, signals, and highway crossing gates shall be installed on concrete foundations.

13.3.2 Equipment Housings

Signal equipment shall operate in the local environment. Design and installation shall accommodate the wayside operating environment.

All housings shall be bungalow type. Equipment and cabinets shall be approved by UTA.

13.4 Electrical Requirements for Signal Work

General electrical requirements necessary for signal work shall be based upon industry practices as appropriate for Salt Lake County.

13.5 Functional Design Requirements

13.5.1 General

The signaling system shall provide the functions of train detection, broken rail detection, signaling for safe train separation, route security through interlockings and grade crossing warning on all portions of the track, except the yard, yard leads, the downtown segment and other street running locations. In street-running segments, LRT traffic signals shall govern. The train operator shall manually control acceleration, deceleration, train speed, door control operation and station dwell time. The signaling system shall be designed to be fail safe (i.e., any malfunction affecting safety shall cause the system to revert to a state known to be safe).

Signal control equipment is to be located along the track only where necessary. All other equipment shall be located in signal equipment houses or cases.

Apparatus typically located along the tracks include:

- Track circuit equipment (impedance bonds and wiring)
- Fixed wayside signals
- Wayside pushbuttons
- Switch indicating signals with number sign identifying number of switch points
- Track switch machines, switch locks, and circuit controllers
- Track switch snow melters
- Signs or other wayside indication equipment
- Switch point indicators
- Highway rail grade crossing equipment

Apparatus located in signal equipment housings include:

- Signaling logic circuitry
- Highway rail grade crossing circuitry
- Track circuit equipment
- Power equipment

13.5.2 Signaling Scheme

13.5.2.1 Double Track Territory

The automatic block signal system (ABS) in double track territory, other than in street-running conditions, shall be arranged to allow for the track to be signaled in both directions. Reverse running shall be under manual block signaling between interlockings but controlled by the home signal. That is, in double track sections a route can be selected in the reverse direction from a home signal. The home signal will perform a block check to the next home signal and display a “proceed only as directed by the

Dispatcher” aspect when opposing signals are locked out. Fixed color light wayside signals shall be located at block limits for signaling. These signals shall be capable of providing clear, stop, and approach indications, depending upon block conditions.

Automatic block signaling as described above shall not be permitted in any street-running environment. Instead, the LRVs shall be governed by LRT signals, which are integrated in to the Advance Traffic Management System.

13.5.2.2 Single Track Territory

The signal system in single track territory shall be a traffic control system arranged for track signaled in both directions. Wayside signal aspects shall be the same as described for double track territory. Approach clearing shall not be implemented for following trains for movements into single track territory when the single track area is occupied by a leading train. However, the following moves shall be permitted using wayside pushbuttons under supervisory direction only.

13.5.2.3 Signal Aspects

The interlocking signal aspects for normal mainline routes shall be the same as those for single and double track territory.

The wayside signal aspects and indications shall be as follows:

<u>Aspect</u>	<u>Indication</u>
Green Auto	Proceed at maximum authorized speed. (Two blocks in advance of the signal are clear.)
Green Home	Proceed straight move or normal direction running, next two blocks are clear.
Flashing Green	(Home) Proceed diverge move or off mainline, next two blocks are clear.
Green Approach	Home signal is clear for a straight move
Yellow	Proceed prepared to stop at the next signal. (Block in advance of the signal is clear.)
Yellow/Yellow	(Approach Signal) Home signal is clear for a diverge move.
Yellow Home	Proceed straight move, prepare to stop at next signal.
Flashing Yellow	(Home) Proceed diverge move, prepare to stop at next signal.
Red	Stop. (Block in advance of the signal is not clear.)
Flashing Red	Stop. Proceed only under Dispatcher direction.
Lunar White (Corridor)	Grade crossing gate is down, proceed through crossing.
Flashing Lunar White (Corridor)	Grade crossing gate is moving, do not proceed through crossing.

Note: If there is more than one turnout being controlled by one home, switch point indicators shall be used.

13.5.2.4 Central Business District (CBD) and Other Street-Running Territory

Railroad type signals shall not be used in a street-running environment. Train detection for preemption or synchronization of motor traffic control devices shall be provided as required by traffic engineering. An interface junction box shall be provided for the tie-in to traffic signal control equipment. At points where

trains cross a parallel traffic lane (e.g., moving from the central medium to a curb lane) bar aspects shall be provided. These aspects will allow the train to cross automobile traffic lanes while red traffic lights are displayed to the automobiles.

The LRV signals at street intersections for the street-running environment are as follows:

- Vertical bar (white)—LRV traffic proceed signal
- Diagonal bar (white)—LRV traffic proceed for turning move at route change point
- Horizontal bar (CBD)—LRV traffic do not proceed signal

Route selection through interlockings (turnouts and crossovers) in street-running territory shall be accomplished by setting up default (preferred) routes which are activated (lined and locked by approach track circuits) or by using a route selector panel to cancel the current route and set up the desired route. Route selector panels are typically placed adjacent to the signal in advance of the appropriate switch or on a station platform in advance of the interlocking. The route selector panel typically contains buttons for:

- Cancel route
- Select normal route
- Select reverse route

The signals for turnouts and crossovers in non-ABS territory are:

- Vertical bar (amber)—Route is locked for straight move.
- Diagonal bar (amber)—Route is locked for diverging move.
- Horizontal bar (red)—Do not proceed. Stop.

13.5.3 Block Signal Design

13.5.3.1 General Block Design Criteria

In determining block limit locations, the braking rate described in Chapter 11, or verified vehicle data derated by 30%, shall be used. There must always be sufficient braking distance in the approach to an occupied block to bring a train to a stop before entering that block. The distance from signal to signal shall be at least as long as the safe braking distance at maximum authorized speed. To achieve this, an additional 30% safety margin shall be added on to the target point calculation.

The location of interlocking signals and interlocking block limits are dictated by the location of track switches. Since the location of these interlocking blocks is fixed, the block limits in approach to or in advance of such locations must be determined relative to the location of interlocking blocks.

13.5.3.2 Specific Block Design Criteria

Double track alignment shall use the minimum number of blocks necessary to achieve a 6.6-minute design headway (for an operational headway of 10 minutes) in the normal direction of traffic at the maximum attainable speeds constrained by civil speed limits.

On single track alignment, a 6.6-minute design headway (for an operational headway of 10 minutes) shall be achieved in both directions for following trains.

Possible locations for block signals limits include the following:

- Stations

- Interlocking limits
- Intermediate locations

13.5.4 Highway Grade Crossing Warning

13.5.4.1 General Criteria

Highway grade crossing warning systems shall include all signs, signals, markings, and warning devices, with their supports. The function of these systems is to permit safe and efficient operation of light rail, freight rail, and highway and pedestrian traffic over grade crossings.

All grade crossing signal systems shall be designed in accordance with federal, state, and local laws and regulations.

The signal control system shall utilize overlay track circuits to control flashing lights, automatic gates, and a bell at public road crossings. Flashing lights, gates, and bells shall be used at selected private road crossings as required by traffic engineering. Grade crossing warning shall be designed for both directions of vehicular and pedestrian traffic on each track. Where interlocking limits are within the approach of a crossing, the crossing control relay shall be controlled by the interlocking and the gate down shall be part of the home signal algorithm. Island circuits will still remain absolute. For reverse running, a maximum of 35 mph shall be used.

13.5.4.2 Specific Guidelines for Grade Crossing Warning Systems

Approach circuits for highway crossing warning devices shall be designed on the basis of 25 seconds at track speed. Where clearing distance exceeds 35 feet, 1 second shall be added to the warning time of 20 seconds for every 5 feet (or fraction thereof) over 35 feet. Clearance distance must be measured in each direction, and the longer distance is used in the calculations. The approach distance shall not be less than 440 feet.

Overlay track circuits shall be designed to retain the crossing warning until the last car has passed the edge of the highway to an engineered distance. This distance shall be determined separately for each grade crossing during final engineering. Flashers shall normally be mounted 12 feet from the near rail, but in no event closer than 10 feet from the near rail.

A test switch and one pushbutton or key cutout for each track shall be provided in a locked box outside of the signal housing.

A train coming out of a switch close to and approaching a highway crossing must proceed at restricted speed, making sure that the warning devices are operating prior to crossing the roadway.

At crossing locations where highway traffic signals are in conflict with crossing warning signals, additional audio frequency overlays (AFOs) shall be provided to provide a traffic preemption signal, such that the preempt shall be effective before the warning system is activated as required by traffic engineering.

On multi-lane highways, cantilever mounted signals shall be used when deemed necessary to improve roadside warning. These flashing light signals shall be mounted over the inner traffic lanes to provide the motorist with an unobstructed view of the signals. Appropriate deterrence shall be provided against zigzag automobile crossings, at locations where warranted.

Crossing warning indicators to provide actual status of crossing gate operation to the train operator shall be provided at all crossing locations equipped with gates. These indicators shall display “flashing white” when the grade crossing system has been activated and “solid white” when the gate arms are fully lowered and level. These indicators shall be displayed for normal and reverse running on both tracks.

13.5.5 Interlocking Control

13.5.5.1 General

The signaling system shall safeguard against opposing or conflicting movements of trains in interlocking areas. Wayside signals shall keep trains at a safe braking distance apart (except the CBD). Reverse running shall be under manual block signaling between interlockings but controlled by the home signal. That is, in double track sections a route can be selected in the reverse direction from a home signal. The home signal will perform a block check to the next home signal and display a “proceed only as directed by the Dispatcher” aspect when opposing signals are locked out. Approach locking or time locking to protect against double occupancy shall be provided for routes in approach to interlockings. No routes are to be cleared through an interlocking until the switches are locked in the proper position. Route locking shall also be provided to prevent movement of a track switch in advance of a train having entered the route. Detector track switch locking shall be provided to prevent operation of a track switch when a train is within the detector area. In single track territory, traffic locking shall be provided to prevent change in direction of traffic throughout any block while it is occupied or while a route has been cleared into the block.

13.5.5.2 Mainline Route Selection

For normal train operation at mainline or terminal interlockings, such as where single track turns to double track, straight through routes shall be aligned and the signal shall clear automatically whenever track circuits detect occupancy by trains on the approach to the interlocking.

Alternate routes shall be selected by means of a wayside pedestal-mounted push button route selector panel.

At locations where double track turns to single track, automatic clearing shall not be implemented for following trains for movements into the single track area when the single track is occupied by a leading train. However, subsequent moves are to be permitted using wayside push button. Automatic clearing shall be allowed into single track territory only when the single track is unoccupied and no route has been cleared into it.

13.5.5.3 Freight Sidings

Freight crossovers on UTA mainline shall be protected by interlockings and conform to the Code of Federal Regulations. Freight sidings from UTA mainline shall be protected by electrically locked switches and derails. The electric lock release shall be controlled by appropriate lock releasing circuitry. For exits from the mainline, the electric lock shall be released by a series overlay track circuit. All conflicting moves in the UTA track area shall be protected by the UTA signal system.

Electric locks shall not be required at freight spurs where procedures will prohibit restoring the switch to its locked position after moving a train into the spur. Circuit controllers shall be provided at all hand throw switches in ABS territory.

13.5.5.4 Turnback Operations

Route selections at terminals with power switch machines shall be set automatically via track circuit occupancy or push button control.

13.5.5.5 Non-Signaled Interlocking with Power Switches

Trains shall be operated on line of sight at reduced speeds in the yard lead interlocking. Normal routes into these interlockings shall be initiated automatically by track circuit occupancy. All other routes shall be initiated via wayside push button. The route aligned shall be indicated by a wayside signal. Detector, time, and route locking shall be provided to prevent switches from being thrown in front of or under a train.

13.5.6 Yard Signaling

Yards shall use hand-operated switches. All train movements within yard limits shall be made at restricted speed, and in accordance with the book of operating procedures pertaining to the yard.

There are to be no signals in the yard. Access to the mainline shall be requested by wayside pushbuttons and controlled by wayside signals or the dispatcher. When a route is cleared for movement onto the mainline, route locking shall be established which locks out the mainline-to-yard moves on that track. In addition, mainline-to-yard movements shall be controlled by wayside signals.

13.5.7 Signal Power

13.5.7.1 Power Source

Signal power shall either be provided from a local commercial power source. Local commercial power shall be used at highway grade crossing locations.

13.5.7.2 AC Signal Power Design Requirements

Signal power (220/110 Vac, 60 Hz) shall be used for the AC power supply, battery charging, signal lighting, track circuits, and switch operation. Where AC signal power is used for a purpose other than signaling, appropriate protection shall be included into the circuitry to avoid the possibility of a ground fault affecting the signal system. Power for switch-snow-melters shall be taken from either gas or local utility (240 Vac).

Battery backup, with at least 8 hours of standby capacity shall be provided at highway grade crossing locations for operation of AFO circuits, gates, flashers, bells, and relay/microprocessor control logic. Current limiting protection shall be provided to guard against overload. The battery for AFO energization shall have voltage sufficient to compensate for line voltage drop at the transmitter locations.

Full wave rectified power supplies shall be provided for electric switch machines. One power supply is required for each crossover and each turnout.

All transformers and rectifiers shall be rated to operate with a load at least 25% greater than the maximum circuit design load to which they are applied.

Surge arresters shall be used for track circuits, cables, and electronic circuit equipment to protect against damage caused by lightning and electrical transients.

13.6 Signal Equipment and Technologies

13.6.1 Track Circuits and Signal Control

In the UTA mainline, coded track circuits using an AC interface shall be used. Through interlocking limits, AC track circuits (vane type) with a phase compensating circuit shall be used. Where high voltage

utility lines in excess of 32 kV are parallel to and within 500 feet of the track, 100-Hz power frequency track circuits shall be used. Otherwise, 60-Hz power frequency track circuits shall be used for interlocking limits in the UTA mainline. Insulated joints are required at interlockings and at track circuit limits. Impedance bonds shall be provided at insulated joint locations for traction power return. Impedance bonds shall have 1500 amp capacity and be tuned or provided sufficient impedance at 60, 100, 156 hertz to be compatible with signal train detection circuits and coded track system. Vital and non-vital logic signal control circuits shall be designed using conventional relay logic and/or vital and non-vital microprocessors meeting the recommendations of the AREMA Signal Manual.

In embedded track sections where train detection is required, single rail AC track circuits shall be used.

13.6.2 Interlocking Equipment

All interlocking hardware shall conform to the recommendations of AREMA Signal Manual. The following criteria highlight some of the major signal equipment for mainline interlockings.

13.6.2.1 Relays

Vital relays shall be of the plug-in type. Vital DC relays, other than special-purpose relays, shall have a minimum of six independent front/back contacts.

Non-vital relays, except for special-purpose relays, shall be of the plug-in type and have an operating voltage range of 12 to 24 Vdc.

All relays shall be configured to provide visual inspection of the relay state (energized or de-energized) without disassembly.

13.6.2.2 Switch Machines

Electrically-operated switch machines shall operate at 110 Vdc and shall be of the high speed type. These switches shall have 110 Vac heaters, of sufficient power commensurate with winter weather conditions in the circuit controller and motor compartments.

Hand-operated switch machines shall be of the locking type, adaptable to either left or right hand installation, such as Alstom Signaling Inc, Model 9, US&S BT-20 or equivalent. The mechanism shall contain a circuit controller to detect switch status when locked, and include a point detector as part of the circuit controller's operation.

Electric switch locks shall be of the low-profile type, such as Alstom Signaling Inc, Model 10, US&S SL-21A or equivalent. The unlocking device shall operate on a 10- to 12-V dc power source.

Switch snow melters shall be installed on all powered track switches that are not otherwise protected from the weather.

13.6.2.3 Signals

- Wayside signals shall be the high type, long range LED color light railway type. Lenses shall be 8¾" in diameter.
- Signals shall include 24" wide backgrounds and shall be mounted on 5" masts 13 feet from bottom of signal to top of rail. Signals shall be equipped with ladders and platforms.
- Signals shall be visible to the train operator at least 1000 feet in advance, and when stopped at the signal.

- All signals shall include LED type lights, transformers, and resistors for 120 Vac operation. ¼" back lights shall be provided on all signal units.
- All LRV traffic signals shall be of similar diameter but square in shape.
- Highway rail grade crossing signals shall be LED type.

13.6.2.4 Interlocking Control Circuits

Interlocking control circuits shall be of microcomputer design. Relays shall only be used where necessary to guarantee vitality of an input or output. Where possible, control logic algorithm shall follow standard signaling logic. In addition to code logic, traditional relay logic shall be provided to illustrate circuit equations. Design qualification testing shall be performed to verify signal indication logic.

13.6.3 Highway Crossing Warning Devices

Standard highway crossing gate mechanisms such as Safetran Model SM, Western Cullen Hayes Model 10 or equivalent shall be used. Standard overlay track circuits such as Harmon AFTAC AFO, US&S AFO-II or equivalent shall be used.

13.6.4 Yard Switching Equipment

Switches within yard limits shall be manually operated by hand throw levers. At the area where the yard is connected to the mainline, switch machines shall be power operated, mainline types. Switch snow melters shall be installed on all powered switch layouts in the yard.

13.6.5 Equipment Housings

Prefabricated instrument houses and cases, of adequate size to house all signal equipment (spare space and future expansion for single track to double track and system upgrading as required), shall be used at various locations along the light rail alignment. These locations would include but are not limited to, interlockings, ABS, highway grade crossings and electric lock locations, switch snow melter installations, and so forth. Instrument house racks shall have standard open frame configuration. Joint use of houses shall be used where practical.

13.6.5.1 Interlocking Housing

Walk-in instrument houses shall be provided at each powered interlocking. These shall be electrically heated and fan cooled to suit the local environment.

13.6.5.2 Grade Crossing Housings

Walk-in houses shall be provided at grade crossing warning locations, except use of non-walk-in type cases may be considered on a site-specific basis.

13.6.5.3 Switch Lock Houses

Instrument cases or houses shall be provided at electrically locked hand operated switch locations as required.

13.6.6 Wire and Cable

Signal system wire and cable shall meet the recommendations of the AREMA Signal Manual and, where applicable, the *National Electric Code*. Low smoke, non-halogen cables shall be used for case wiring. All wire shall be numbered or color coded.

13.6.6.1 Instrument Housings

- All incoming cables shall be terminated on a main terminal board which shall be accessible from both sides. Each wire, including spares, shall be terminated on a disconnect type terminal arrangement which will allow the circuit to be opened without removing the wire. Field cables shall be routed on the side of the terminal to which it is connected. Wires shall not cross house wiring terminals.
- All incoming pairs shall be equipped with series arresters except those run underground to local devices.
- All track leads shall be equipped with series and shunt arresters.
- In instrument houses, the wiring shall lead directly from the main terminal board to the apparatus. Energy buses shall loop feed from the main terminal board to each apparatus rack terminal board. All inter-rack wiring shall be accomplished by running single conductor wire between apparatus; this wiring shall not be terminated on the rack terminal board. Internal wiring between apparatus racks and main terminal boards of instrument housings shall be carried overhead at rack top level in wire troughs.

13.6.6.2 Wayside Cables

Local cables, connecting instrument cases or houses with trackside functions, such as signal lighting, switch control, and track circuits, shall be direct burial cable. Main express cable connecting adjacent trackside locations (such as from interlocking to interlocking) shall be direct burial or suspended cable. Signal power cable shall also be direct burial or suspended cable. Duct work for cable routing shall be considered for installation cost effectiveness and protection at critical areas such as grade crossings.

Cables of all categories in imbedded track or at highway rail grade crossings shall use conduit.

13.6.7 Backbone Signal/Communications Duct Bank

An exclusive use UTA signal and communication “backbone” conduit system (duct bank) consisting of four 1½” conduits will be provided along the entire length of the corridor. The following color coded conduits will be used: red stripe on black, black, orange, and gray. Fiber will be placed in the conduit, according to the specifications provided for each project. Pull boxes will be located every 1,200 feet maximum along the duct bank run, or as designated in project drawings, and at each station.

The duct bank will be located on UTA property along the entire corridor. Laterals consisting of four 2” conduits will be placed from the duct bank to each power control cabinet at platforms, traction power substations, traffic signal controllers, and to all signal equipment house locations as identified in the project plans and specifications.

13.7 Installation, Testing, Manuals, and Training

13.7.1 Installation

Installation of signal equipment shall conform to the applicable sections of the AREMA Signal Manual and/or manufacturer’s recommended methods. Staged construction shall be as indicated in the integrated construction schedule.

13.7.2 Testing

All signal components, subsystems and systems shall be subject to the applicable factory tests, field tests and inspections for the purpose of verifying design and nameplate rating, and ensuring proper performance, safety, reliability and compliance with specifications. Test procedures and inspections shall generally be conducted according to manufacturer's specifications.

13.7.3 Training

Training programs shall familiarize UTA personnel in all aspects of operations and maintenance associated with the signal system. Technical manuals shall comprehensively address all phases of signal system operations, maintenance, repair and spare parts provisioning.

END OF CHAPTER 13.



Utah Transit Authority Light Rail Design Criteria

Chapter 14 Communications

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 14 COMMUNICATIONS

14.1 General

This chapter describes the functional requirements for communications and identifies important interface criteria to be used in the development of the final design specifications. Essential communications for wayside signaling, LRV traffic control, and other communications needs control will require a cable transmission system. Voice radio communications will be satisfied with the two-way “Trans Dat” data radio system. Expansion of the bus radio system for joint use with light rail is a desirable objective. The specification for radios shall be a procurement contract which shall include training, technical support and commissioning services. Field construction such as antenna installation and base station site provisions shall be covered under separate work.

14.1.1 *Electromagnetic Interference (EMI)*

The communications system is designed to operate within the electromagnetically hostile environment of the electrified line. The system design shall mitigate any possible interference that could be caused by the communications system to other electrical systems such as signals, vehicles, and traction power.

14.1.2 *Installation, Testing, Manuals, and Training*

Field installation procedures that are consistent with industry practice and the radio manufacturer’s recommendations shall be employed. *(All radio installations will be performed under UTA supervision at UTA facilities.)*

Actual testing in the factory and in the field shall be certified as being done in accordance with approved plans and procedures. Field tests must be witnessed. Factory tests may be witnessed at the discretion of UTA. Requirements for the publication of operating and maintenance (O&M) manuals as well as requirements for UTA personnel training shall be developed as necessary.

14.1.3 *Warranty and Initial Provisioning*

Contractor warranty of in-service equipment shall be compulsory for a specified period such as 1 year after delivery, or after installation and acceptance testing. The required warranty period shall be stated in the contract provisions. During the development of preliminary and final specifications, a maintenance philosophy and the corresponding spares provisioning shall become evident. An allowance has been made for the initial provisioning based on the contractor’s recommendations.

14.1.4 *Communications Interfaces*

The communications system design, construction, and testing activities must be fully interfaced with other project activities. The most significant interfaces are with the light rail vehicles and, if required, the cable transmission system. The communications contract shall provide for the design and furnishing of the train radios. The radios shall be installed in the vehicles under UTA supervision. Prototype tests interfacing with the vehicles shall be required for any new or modified unit. Particular areas of concern are the requirements for mechanical installation, cabling, power supply, cab controls, antenna, and for interface with the signal system, cable transmission system, and the software changes needed to merge the LRT system with UTA’s existing radio dispatching system.

14.1.5 *Backbone Signal/Communications Duct Bank*

See Section 13.6.7 for signal/communications duct bank requirements.

14.2 Two-Way Radio

14.2.1 System Description

Two-way radio is mandatory for the communications between the train operator and the control center. The initial requirements can be met with the existing UHF system.

The method of operation would be half-duplex, in which voice conversation occurs in only one direction at a time. With a fleet of up to 75 vehicles, the half-duplex radio operation should be completely satisfactory. Train control by voice radio will occur at the start, end, and during each run. Train operators may be required to report by voice conversation or data canned messaging via the train radio system all schedule delays using procedures established. .

Automatic train identification and an operator initiated emergency alarm shall be incorporated into the UTA "Trans Dat" system.

Actual test measurements of coverage shall be conducted as required.

14.2.2 Vehicle Radios

A panel mounted mobile data terminal (MDT) control head is planned for each of the two cabs on the light rail vehicle. Separate MDT radios, antennas, transmission lines, and power supplies for each cab shall eliminate the need for trainline wiring to support the radio. A speaker shall permit the operator to monitor all radio conversation at the discretion of the dispatcher. A handset, when lifted, shall be used for talking and listening.

The mobile radio equipment shall be installed in the light rail vehicles after UTA acceptance of the light rail vehicles.

14.2.3 Mobiles and Portable Radios

Quality mobile radios, portable radios, and accessories which are commercially available shall be secured to support the field operations and maintenance. The portable radios shall be compact, have multiple channel capability, and be rugged in construction meeting existing UTA specifications or the requirements of MIL-SPEC810D.

14.3 Cable Transmission System

Critical communication links between signal wayside equipment, auto traffic controllers, and the control center may be provided through the use of fiber optic cabling. Public address announcements and messaging at stations shall also be supported by the fiber optic network. To permit the cable routing for anticipated communications needs as well as future communications, conduit and duct with sufficient spare requirements shall be developed and coordinated as part of the civil and structural work.

14.4 Radios Used During Construction

The construction of the UTA light rail system shall be supported by the two-way radio system. The procurement of portable radios and accessories shall be accelerated for early delivery to provide a two-way network for use during the field construction activities.

END OF CHAPTER 14.



Utah Transit Authority Light Rail Design Criteria

Chapter 15 Fare Collection Equipment

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 15 FARE COLLECTION EQUIPMENT

15.1 General

Patrons shall buy tickets and passes or use transfers for passage on the LRT system. The ticket, pass, or transfer, in each case, evidences payment of fare and enables barrier-free fare control throughout the LRT system. No fares or currency shall be collected aboard LRT trains. Self-service ticket vending machines (TVMs), located on LRT station platforms, shall make change and vend single ride tickets and day passes, with the future capability of vending multi-trip tickets and validating tickets.

15.1.1 Conditions of Service

The TVM equipment shall be capable of satisfactory operation in the ambient conditions described in Section 2.6.

The front plate of the TVM shall have the capability to display permanent and contemporary information for passengers.

The equipment shall be installed in locations with clear view from all directions and may be exposed to the weather and ambient conditions, including exposure to sunlight, snow and rain. Installations shall be at unmanned passenger stations and at sidewalk locations on existing streets which shall be exposed to the general public.

Systems equipment including vehicles, electric traction supply and distribution system, signal system and fare collection equipment shall be capable of maintaining operation within the climatic conditions of the Salt Lake City area. The following data are to be used as the design weather conditions:

Temperature range	-30 to +110 °F
Relative humidity	8 to 100%
Maximum rainfall in 24 hours	6.7 inches
Maximum snowfall in 24 hours	18.4 inches
Maximum wind speed	71 mph
Freezing rain	Average of 1 time per year
Elevation	4,330 feet

All facilities shall be designed to accommodate safe storage and/or removal of snow, melting snow, and ice.

15.1.2 Handicapped Accessibility

TVMs shall comply with the requirements of 49 CFR Parts 27, 37, and 30 implementing the provisions of the Americans with Disabilities Act of 1990 (ADA-90) as follows:

- Each machine shall be on an accessible route to the station.
- Controls for user activation shall comply with the following requirements:
 - Clear Floor Space—Clear floor space that allows a parallel approach by a person using a wheelchair shall be provided at controls, dispensers, receptacles, and other operable equipment.

- Size and Approach—The minimum clear floor or ground space required to accommodate a single, stationary wheelchair and occupant is 30 inches by 48 inches. The minimum clear floor or ground space for wheelchairs may be positioned for forward or parallel approach to an object.
- Relationship of Maneuvering Clearance to Wheelchair Spaces—One full unobstructed side of the clear floor or ground space for a wheelchair shall adjoin or overlap an accessible route or adjoin another wheelchair clear floor space.
- The highest operable part of controls, dispensers, receptacles, and other operable equipment shall be placed within at least one of the reach ranges specified below:
 - Forward Reach—If the clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 inches. The minimum low forward reach is 15 inches.
 - Side Reach—If the clear floor space allows parallel approach by a person in a wheelchair, the maximum high side reach allowed shall be 54 inches and the low side reach shall be no less than 9 inches.
- Controls and operating mechanism shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls shall be not greater than 5 pounds per foot (22.2 N).
- Instructions and all information for use shall be made accessible to and independently usable by persons with vision impairments.

15.2 Functions of the TVM

15.2.1 General

The TVMs shall be a standard production model which shall have a certifiable record of reliable, low maintenance operation on one or more existing transit systems under service conditions similar to those indicated herein for a period not less than the past 3 years. The components of the TVM shall be modules capable of field replacement.

The TVM shall have a certifiable record of satisfactory performance reliability on similar types of installations.

The failure rate shall not exceed 1.5 per TVM per month (i.e., the number of failures in each 3-month period divided by the number of TVMs in the group shall yield a quotient not greater than 4.5), nor shall the failure rate exceed 1 per 8,000 tickets vended (i.e., the number of failures in each 3-month period when multiplied by the number 8,000 and that product divided by the total number of tickets vended by all TVMs in the group, shall yield a quotient not greater than unity).

Listing and labeling of the TVM shall conform to the following:

- For TVMs of U.S. manufacture, the TVMs shall comply with the standards of a testing organization nationally recognized in the United States, such as UL.
- For TVMs of foreign manufacture, a certificate or other evidence that the TVM is in compliance with the standards of a testing organization which is nationally recognized in the country of manufacture.

15.2.2 Power Supply

The TVMs shall operate on primary power from a single phase, 120-V, 60-Hz service having a voltage variation of +10% and -15%. Power shall enter the base of the TVM.

15.2.3 Mounting

The TVM shall include a base, either integral or separate as a pedestal, suitable for mounting to a concrete footing or floor.

15.2.4 Tariff

The TVM shall vend tickets ranging in value from \$0.05 to \$99.95 at selected \$0.05 increments. The value of any ticket in the tariff shall be adjustable by UTA to accommodate tariff revisions on each TVM installed and in service. The number of values in the tariff shall be at least 32.

15.2.5 Vending

A passenger shall select a ticket or multiples of the same ticket by pressing a corresponding push-button on the selection keyboard. An LCD display, with backlighting or equivalent, easily distinguishable in sunlight, shall show the correct fare for the ticket selected.

Alternatively, a 9-inch diagonal programmable LCD screen with backlighting or equivalent easily distinguishable in sunlight, may be provided to direct the customer through the steps of the transaction, with the customer's responses being entered through function keys as in ATM operations. The screen shall be capable of displaying 40 alphanumeric characters per line and up to 25 lines at a time and shall be shaded from direct sunlight by means of a hood or optical filter.

A passenger may deposit a single bill and/or multiple coins in the TVM and the display shall decrease to zero as money is inserted. When the money is sufficient to pay the fare, as shall occur when the display reaches zero, the TVM shall automatically print and vend the ticket selected. Change shall be provided.

In the event a passenger decides to discontinue the payment after selection and before the display decreases to zero, he/she may do so by depressing the cancel button on the face of the TVM. The TVM shall then return the amount of money the passenger has deposited.

In the event a passenger simply discontinues payment of the selection before the display decreases to zero, the TVM shall self cancel in the manner indicated above after a period adjustable from 10 to 60 seconds.

15.2.6 Coin Handling

A single vertically oriented coin slot shall be provided. The coin slot shall be closed normally except when vending is enabled.

The following U.S. coins shall be accepted:

	<i>Diameter</i>	<i>Thickness</i>	<i>Weight</i>
UTA-issued tokens	0.900"	0.050"	*
Half-dollar (50¢)	1.205"	0.086"	11.30 g
Quarter (25¢)	0.955"	0.067"	5.67 g
Dime (10¢)	0.705"	0.053"	2.268 g
Nickel (5¢)	0.835"	0.078"	5.00 g
Minting tolerances	+/-0.003"	±/-0.002"	+/-4%

The TVM shall reject coins, slugs or other objects other than the above coins and tokens and return them to the user via a reject exit. The coin acceptor shall have a verifiable adjustment of its tolerance to accept coins. The adjustment shall be controllable without return to the manufacturer or requiring specialized technical services on-site.

Design of the coin slot shall minimize the possible entry of foreign objects including liquids and dirt. Where such objects are inserted in the coin slot, the coin tracks and coin acceptor shall have the maximum possible self-clearing ability.

Accepted coins shall ultimately be collected and temporarily vaulted prior to removal to the counting room. The coin vault shall have a volume of not less than 425 cubic inches.

15.2.7 Bill Handling

A single horizontal slot shall be provided for accepting or returning bills. A bill acceptor capable of accepting U.S. \$1, \$5, \$10 and \$20 bills shall be provided. The bill acceptor shall not have an escrow unit but shall be capable of returning one bill in case a transaction is canceled.

15.2.8 Tickets

The TVM shall vend tickets having physical dimensions within the following ranges:

- Length: 2.0 to 3.375 inches
- Width: 0.75 to 2.125 inches
- Thickness: 0.007 to 0.010 inches

Tickets shall be vended on pre-printed ticket stock. After payment is received for the fare of a selected ticket, the TVM shall print the following:

- Expiration time in 12-hour notations, including a.m. or p.m. designation, in 10-minute increments derived from an internal clock
- Month, day, and year in 6 numerals (2 numerals for each)
- Boarding station name, at least 13 letters
- Machine number, up to 3 digits
- Amount of fare paid

The printer shall print the indicated data in programmable variations of format at the rate of at least 150 characters/second.

The TVM shall issue the vended ticket via a weather protected hopper designed to minimize the possibility of jamming and vandalism. Access to the hopper shall be through a sprung plastic swivel door; the hopper shall have a drain hole.

15.2.9 Protection Against Theft

The design of the TVM shall provide separate secure locked access to the interior for maintenance and separately to the money. Each access on each TVM shall be by a lock designed to minimize vandalism and theft.

The locks to each access on any TVM shall be keyed differently according to function. However, all TVMs shall be keyed alike.

All keys shall be controlled and registered equivalent to level IV, Medeco Security Locks, Inc.¹

All locks shall be flush mounted.

Two coin and bill vaults shall be provided for each TVM. One vault shall normally be in service in each TVM. The second vault shall be used in rotation for revenue collections. Each vault shall have security from access such that, when removed from the TVM, it is automatically locked. Additional spare vaults shall be required for use during service and maintenance of the two base vaults.

Each vault shall be fitted with a device that is encoded with a number unique to that container. The device shall be used by the TVM to automatically identify the vault serial number. In addition, each vault shall be individually identified by a unique, permanently inscribed serial number. The inscribed serial number shall be identical to the number automatically readable by the TVM.

The total amount of money by denomination deposited into a vault shall be monitored from the time the vault is inserted in the TVM. This monitoring shall allow the contents to be reported when the vault is replaced and prevent the vault from overfilling without warning.

The TVM shall be constructed to enhance protection against theft.

All screws shall be covered over. All hinges shall be covered over or constructed so as to prevent entry by drilling.

All exterior seams shall be overlapping.

The design shall provide for a set of contacts to enable a local security alarm in the event unauthorized tampering opens any access door more than 0.08 in. An internal klaxon, or equivalent device, shall locally annunciate the security alarm. A switch shall be provided to select enablement or suppression of the klaxon.

¹Medeco Security Locks, P.O. Box 1075, Salem, Virginia 24153-1075.

15.2.10 Other Design Requirements

The TVM shall have interlocks such that the coin and bill slots shall close and an out-of-service sign shall be shown or illuminated if the TVM detects a bill, coin or paper jam, runs out of paper, or any other malfunction which shall completely disable the TVM.

The TVM shall be provided with an internal battery to operate its clock during a power interruption of up to 6 hours.

The TVM shall accumulate and summarize data to enable audit of vending transactions occurring between vault replacements. These data shall include:

- The number of vended tickets by ticket class
- Revenue collected by ticket class
- The sum of all vended tickets and total revenue collected

The TVM shall generate and imprint an audit ticket with these data. The audit ticket shall be suitable for inserting in the vaults removed when replaced for purposes of the counting room's audit.

As an alternative to inserting the audit ticket in the vault, the TVM shall automatically generate the serial identification number of the removed vault either during removal or immediately following removal and before the replacement vault is inserted.

The TVMs shall have a system which shall automatically and independently transfer the indicated audit data from each TVM for subsequent reading and processing on UTA's central processor.

Each TVM shall be equipped with a 3½-inch, high-density disk drive where service personnel may download statistical information periodically onto a 3½-inch disk.

Construction materials for the TVM shall be as defined below:

- The TVM shall use stainless steel for the construction of the base and the enclosure.
- All pushbuttons, function keys, and numeric keys on the exterior of the TVM shall be metal and shall not be removable from the exterior of the machine.
- All displays on the exterior of the TVM are to be protected by shatter resistant plexiglass or polycarbonate covers.
- Any messages to be permanently affixed to display windows are to be applied by silk screening.
- Construction and installation shall be in accordance with the requirements of the NEC.

15.2.11 Failure Modes

In general, unless for cause of security, or for a transaction of improper value, the TVM shall fail gracefully (i.e., the mode of failure shall permit as much of the TVM to function as possible).

In the event there is a failure of the commercial power energizing the TVM, the TVM shall lose no data, nor require reset of the clock, and for any transaction in progress, the TVM shall either allow the transaction to conclude, or cancel the transaction at the point of interruption.

END OF CHAPTER 15.



Utah Transit Authority Light Rail Design Criteria

**Chapter 16
Corrosion Control**
Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 16 CORROSION CONTROL

16.1 General

This chapter describes the requirements for a corrosion control system design which shall prevent premature corrosion failure; minimize stray current on underground structures and be economical to install, operate and maintain. The system shall monitor, measure, and provide protection, when required.

16.2 Scope

Three types of corrosion control shall be implemented as part of the light rail system: soil and water corrosion control, stray current corrosion control and atmospheric corrosion control.

The design criteria for each of these categories, and their implementation, shall meet the following objectives:

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

16.2.1 *Soil and Water Corrosion Control*

The goal of this design is to prevent corrosion of structures due to soil and water. Soil and ground water characteristics shall be determined and documented during boring surveys. Analysis of the data obtained from on-site borings shall be the basis for corrosion control designs. The soil/rock samples should be analyzed for resistivity (or conductivity), moisture content, pH, chloride and sulfate ion concentrations and for the presence of sulfides.

Normally, affected structures, as in the conditions listed below, shall be protected against the environment by coating, insulation, electrical continuity and/or cathodic protection, whichever is applicable.

Structures which may be affected by soil and water corrosion typically include, but are not limited to:

- Buried and on-grade reinforced concrete structures
- Pier and pile structures
- Ferrous piping (water, fire, sewage, etc.)
- Hydraulic elevator cylinders
- Underground storage tanks
- Steel trackwork
- Electrical Conduits
- Copper piping

16.2.1.1 **Materials of Construction**

All pressure and non-pressure piping and conduit shall be non-metallic, unless metallic materials are required for specific engineering purposes.

Aluminum and aluminum alloys shall not be used in direct burial applications.

If non-native fill is to be used for backfilling concrete or ferrous structures, then it shall meet the following criteria:

- pH 6 to 8
- Maximum chloride ion concentration of 250 ppm
- Maximum sulfate ion concentration of 200 ppm

Use of fill material, which does not meet one or any of the preceding criterion, may be acceptable after review and approval by UTA.

16.2.1.2 Safety and Continuity of Operations

Corrosion control protection shall be required for those facilities where failure of such facilities caused by corrosion may affect the safety, or interrupt the continuity of operations.

16.2.1.3 Accessibility of Installations

Permanent test facilities installed with certain corrosion control provisions shall be accessible after installation, allowing for periodic maintenance and monitoring.

16.2.1.4 Special Considerations

Installation of corrosion control measures for facilities owned by others, but designed as part of the transit project, shall be coordinated through UTA or its representative. This coordination shall resolve design and construction conflicts to minimize the impact on other system elements.

16.2.1.5 Coatings

Coatings specified for corrosion control of buried metallic or concrete facilities shall satisfy the following criteria:

- Minimum volume resistivity of 10,000,000,000 ohm-centimeters (10 Billion ohm-centimeters).
- Minimum thickness as recommended for the specific system, but not less than 15 mils.
- A chemical or mechanical bond to the metal or concrete surface. Pressure-sensitive systems are not acceptable; non-bonding systems may be used in special instances, after review and approval by the UTA.
- Minimum 5-year performance record for the intended service.
- Mill application wherever possible, with field application of a compatible paint or tape system.
- Mechanical characteristics capable of withstanding reasonable abuse during handling and earth pressure after installation for the design life of the system.

16.2.1.6 Generic Coating Systems

Generic coating systems include but are not limited to the following:

- Extruded polyethylene/butyl based system
- Coal-tar epoxies (two component systems)
- Polyethylene-backed butyl mastic tapes (cold applied)
- Bituminous mastics (airless spray)

16.2.1.7 Electrical Insulation of Piping

Devices used for electrical insulators for corrosion control shall include nonmetallic inserts, insulating flanges, couplings, unions, and/or concentric support spacers. Devices shall meet the following criteria:

- A minimum resistance of 10 megohms prior to installation.
- Sufficient electrical resistance after insertion into the operating piping system such that no more than 2 percent of a test current applied across the device flows through the insulator, including flow through conductive fluids if present.
- Mechanical and temperature ratings equivalent to the structure in which they are installed.
- Internal coating (except complete non-metallic units) with a polyamide epoxy for a distance on each side of the insulator 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 shall be based on separate evaluation.
- Devices (except non-metallic units) buried in soils shall be encased in a protective coating.
- Devices (except non-metallic units) installed in chambers or otherwise exposed to partial immersion or high humidity shall have a protective coating applied over all components.
- Inaccessible insulating devices, such as buried or elevated insulators, shall be equipped with accessible permanent test facilities.
- A minimum clearance of 12 in shall be provided between new and existing metallic structures. When conditions do not allow a 12 in clearance, the design shall include special provisions to prevent electrical contact with existing structure(s).

16.2.1.8 Electrical Continuity of Piping

Electrical continuity shall be provided for all non-welded metallic pipe joints and shall meet the following criteria:

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

16.2.1.9 Cathodic Protection

Cathodic protection shall be accomplished by sacrificial galvanic anodes to minimize corrosion interaction with other underground utilities. Impressed current systems shall be used only when the use of sacrificial systems is not technically and/or economically feasible. Cathodic protection schemes that require connection to the transit system negative return system, in lieu of using a separate isolated anode groundbed, shall not be permitted.

Cathodic protection system design shall be based on theoretical calculations that include the following parameters:

- Estimated percentage of bare surface area (minimum 1 percent).
- Cathodic protection current density (minimum of 1.0 ma/ft² of bare surface area).
- Estimated current output per anode.

- Estimated total number of anodes, size, and spacing.
- Minimum anode life of 25 years (minimum 50 percent efficiency).
- Estimated anode groundbed resistance.

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

Test facilities consisting of a minimum of two structure connections, one reference electrode connection, conduits and termination boxes shall be designed to permit initial and periodic testing of cathodic protection levels, interference currents, and system components (anodes, insulating devices, and continuity bonds). The designer shall specify the locations and types of test facilities for each cathodic protection system.

16.2.1.10 Ferrous Pressure Piping

All new buried cast iron, ductile iron, and steel pressure piping shall be cathodically protected. System design shall satisfy the following minimum criteria:

- Application of a protective coating to the external surface of the pipe (see 16.2.1.6).
- Electrical insulation of pipe from interconnecting pipe, other structures and segregation into discrete electrically isolated sections depending upon the total length of piping (see 16.2.1.7).
- Electrical continuity through the installation of copper wires across all mechanical pipe joints other than intended insulators (see 16.2.1.8).
- Permanent test/access facilities to allow for verification of electrical continuity, electrical effectiveness of insulators and coating, and evaluation of cathodic protection levels, installed at all insulated connections. Additional test/access facilities shall be installed at intermediate locations, either at intervals not greater than 200 ft, or at greater intervals determined on an individual structure basis.
- Number and location of anodes and size of rectifier (if required) shall be determined on an individual structure basis.

16.2.1.11 Copper Piping

Buried copper pipe shall be electrically isolated from non-buried 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 shall be electrically isolated from building structural elements. The insulator should be located inside the structure and not buried.

16.2.1.12 Gravity Flow Piping (Non-Pressured)

Corrugated steel piping shall be internally and externally coated with a sacrificial metallic coating and a protective organic coating.

Cast or ductile iron piping shall be designed and fabricated to include the following provisions:

- An internal mortar lining with a bituminous coating on ductile iron pipe only (not required for cast iron soil pipe).

- A bonded protective coating or unbonded dielectric encasement on the external surfaces in contact with soils (AWWA Standard C105).
- A bituminous mastic coating on the external surfaces of pipe 6 inches on each side of a concrete/soil interface.

Reinforced Concrete Non-Pressure Piping. Reinforced concrete non-pressure piping shall include the following provisions:

- Water/cement ratios meeting the minimum provisions of AWWA.
- Maximum 250 ppm chloride concentration in the total concrete mix (mixing water, cement, admixture and aggregates).

16.2.1.13 Electrical Conduits

Buried metallic conduits shall include the following provisions:

- Galvanized steel with PVC or other coating acceptable for direct burial, including couplings and fittings. The PVC coating is not required when conduits are installed in concrete.
- Electrical continuity through use of standard threaded joints or bond wires installed across non-threaded joints.

16.2.2 Stray Current Corrosion Control

The stray current control measures shall be incorporated into the design of system elements to include the vehicle service facility, traction power system, the trackwork, reinforced concrete structures and walls, metallic pipes and utility systems. Protection measures shall be applied with the goal of controlling the stray current within acceptable levels, as determined in the design process. Recording charts shall be obtained to determine effects/magnitude of stray currents, if present, on existing utility installations where deemed necessary, and to serve as documented reference for future investigations.

16.2.2.1 Positive Distribution System

The positive distribution system shall be operated as an electrically continuous bus with no breaks, except during emergency or fault conditions, and with intentional electrical segregation of yard, shop, and mainline traction power distribution systems.

16.2.2.2 Negative Distribution System—Resistance-to-Earth Criteria

The mainline running rails, including special trackwork and all ancillary system connections, shall be designed to have the following desirable in-service resistances per 1,000 feet of track (2 rails):

- Aerial—500 ohms
- At Grade—250 ohms

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

Rail-to-ground resistance shall be monitored before and after construction to detect variations or decreases in the resistance. Investigations shall be initiated as soon as a low resistance reading is detected and the adverse condition(s) repaired immediately. Delay of repair(s) could impact additional construction elements and result in higher repair costs.

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

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

16.2.2.3 Utility Structures

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

Metallic Facilities (Systemwide)

- Pressure or non-pressure piping exposed within tunnels or crawl spaces or embedded in concrete inverts shall not require special provisions.
- Pressure piping that penetrates tunnel, foundation, or station walls shall be electrically insulated from the external piping to which it connects and from watertight wall sleeves. Electrical insulation of interior piping from external piping shall be made on the inside of the tunnel or station.
- All buried pressurized piping shall meet the criteria specified in 16.2.1.10.

16.2.2.4 Facilities Owned by Others

Replacement/Relocated Facilities.

Corrosion control requirements for buried utilities installed by the owner/operator as part of transit construction shall be the responsibility of the individual utility owner/operator. Minimum stray current corrosion control criteria, when guidance is requested by the utility owner/operator, shall be in accordance with paragraph “Existing Utility Structures” below.

Relocated or replaced utilities installed by transit contractors as part of contractual agreement between the transit agency and the utility, shall be installed in accordance with the utility owner specifications and shall include the following minimum provisions. These provisions are applicable to ferrous and reinforced concrete pressure piping. Other materials and structures will require individual review.

- Electrical continuity through the installation of insulated copper wires across all mechanical joints for which electrical continuity cannot be assured (see 16.2.1.8).
- Electrical access to the utility structure via test facilities installed in accordance with 16.2.1.9.
- 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, shall be based on the characteristics of the specific structure and to not adversely effect the existing performance within the environment.

Existing Utility Structures

The need for stray current monitoring facilities shall be jointly determined by UTA and the utility operators. If utilities require assistance, the following minimum provisions shall be suggested.

- Test facilities may be installed at select locations for the purpose of evaluating stray earth current effects during start-up and revenue operations. Guidelines for location of test facilities shall be as follows:
 - a. At all utility crossings with the system, and on structures that are within 300 ft and parallel to the system right-of-way.

- b. At locations on specific utility structures that are within 300 ft of the system traction power substations.

16.2.2.5 Bridge Structures

The following guidelines give the basic requirements for stray current control for concrete deck girder bridges. Providing electrical interconnection will mitigate internal stray current corrosion.

Deck

Provide an insulating coating on the top surface of the deck. Provide an extra (non-structural) lap-welded continuous top longitudinal #4 rebar in the deck slab at each girder and within one foot of the inside face of the ballast walls. Weld connect the above mentioned longitudinal bars to a transverse collector bar (#9 rebar) at each bent diaphragm, abutment diaphragm and abutment backwall.

Seat Type Abutments

Provide transverse collector bar (#9 rebar) in the top of abutment backwalls. Weld connect all backwall exterior face vertical rebar to the collector bar. Exothermic weld on #2/0 copper cable to each collector bar in the backwall and the abutment diaphragm. Bring cables through abutment backwall (no duct), direct bury in ground to #5 pull box at end of wingwall. Apply a membrane insulation on abutment diaphragm end surface. Use epoxy coated approach slab tie bars the full width of bridge. Permit only high density mortar blocks. Permit only precast prestressed concrete piles or cast-in-drilled holes piles. Provide neoprene sheet insulation between the ground and bottom of pile cap.

Pier Caps

Provide elastomeric bearing pads. Exothermic weld on copper cable to each collector bar in the bent diaphragms. Bring cables through bent joint to connect collector bars in the diaphragm.

Traction Power

Epoxy-coat pole anchorage hardware to be embedded in concrete. Epoxy-coat OCS hanger anchorages cast into a bridge soffit or elsewhere.

Deck Drains

Insulate drain systems.

16.2.3 Atmospheric Corrosion Control

Alternating wet and dry weather together with industrial and chemical pollutants can contribute to increased corrosion rates of exposed metal structures and hardware. The atmospheric corrosion conditions shall be derived from previous baseline stray current field reports. Designs and associated coatings shall be based on recommendations of the reports and shall be used to significantly decrease atmospheric corrosion rates.

The purpose of this criteria is to insure the function, preservation and appearance of LRT structures exposed to the environment in the most cost effective manner. Criteria includes the following:

- Materials selection: acceptable materials shall have proven past performance records for the service application.
- Protective Coatings: barrier or sacrificial coatings shall be used on steel.
- Design: recess moisture traps and dissimilar metals shall be avoided.
- Sealants: accumulation of moisture in crevices shall be prevented by use of sealants.

16.2.3.1 Scope

Structures possibly affected by atmospheric corrosion shall be determined. Identification of structures shall include but not be limited to:

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

Coatings shall have established performance records for the intended service and be compatible with the base metal to which they are applied.

Coatings shall be able to demonstrate satisfactory gloss retention, color retention, and resistance to chalking over their minimum life expectancies.

Coatings shall have minimum life expectancies, defined as the time prior to major maintenance or reapplication, of 15 to 20 years.

Metallic-Sacrificial Coatings

Acceptable coatings for carbon and alloy steels for use in tunnels, crawlspaces, vaults, or above grade are as follows:

- Zinc (hot-dip galvanizing [2 oz. per sq. ft] or flame sprayed)
- Aluminum (hot-dip galvanizing [2 mil thickness] or flame sprayed)
- Aluminum-zinc
- Cadmium and electroplated zinc (sheltered areas only)
- Inorganic zinc (as a primer)

Organic Coatings

Organic coating systems shall consist of a wash primer (for galvanized and aluminum substrates only), a primer, intermediate coat(s), and a finish coat. Acceptable organic coatings, for exposure to the atmosphere, are as follows:

- Aliphatic polyurethanes
- Vinyl copolymers
- Fusion-bonded epoxy polyesters, polyethylenes, and nylons
- Acrylics, where not exposed to direct sunlight
- Alkyds, where not exposed to direct sunlight
- Epoxy as a primer where exposed to the atmosphere or as the complete system where sheltered from sunlight

Conversion Coatings

Conversion coatings, such as phosphate and chromate coatings, shall be used as pretreatments only for further application of organic coatings.

Ceramic-Metallic Coatings (Cermets)

This hybrid-type coating system is acceptable for use on metal panels and fastening hardware.

Sealants

Seal all crevices with a polysulfide, polyurethane or silicone sealant.

Barrier Coating System

Use one of the following barrier coating systems where corrosion protection is needed but appearance is not a primary concern:

- Near white blast surface according to SSPC-SP 10. Follow with a three coat epoxy system.
- Commercial blast surface according to SSPC-SP 6. Follow with a two coat inorganic zinc and high build epoxy system.
- Near white blast surface according to SSPC-SP 10. Follow with a three coat epoxy zinc, high build epoxy system.
- Apply all coatings according to manufacturer's specifications.

Use one of the following barrier coating systems where corrosion protection and good appearance are needed.

- Near white blast surface according to SSPC-SP 10. Follow with a three coat inorganic zinc, high build epoxy, polyester urethane system.
- Near white blast surface according to SSPC-SP 10. Follow with a three coat vinyl system.
- Commercial blast surface according to SSPC-SP 6. Follow with a three coat epoxy zinc, high build epoxy and polyester urethane system.
- Commercial blast surface according to SSPC-SP 6. Follow with a three coat epoxy zinc, high build epoxy and acrylic urethane system.
- Apply all coating according to manufacturer's specifications.

Graffiti-Resistant Coatings

Surfaces which are accessible to graffiti shall be protected with a graffiti-resistant coating. This includes concrete and painted steel surfaces within stations such as walls, columns, and equipment enclosures. All such areas shall be protected up to a height of 10 feet. The coating shall be a urethane-type coating and shall be applied in accordance with the manufacturer's latest published instructions.

16.2.4 Grounding

16.2.4.1 Scope

The purpose is to insure that grounding and corrosion control requirements do not conflict so as to render either system ineffective. The key to accomplishing complementary systems is proper location of insulation points and proper means of grounding system. The grounding designs shall be reviewed by corrosion personnel to assure that the systems are not compromised while providing a safe and reliable system. Facilities addressed include the Aerial Structures.

16.2.4.2 Design and Coordination of Grounding Systems

Structures on the aerial structure such as poles, handrails, cable trough components, and other metal components shall be electrically isolated from the top layer of reinforcing steel and deck. At each end of

the structure, insulated cables shall be exothermically welded to the reinforcing steel and terminated in an appropriately sized and conveniently located weatherproof junction box or manhole. Support piers and abutments shall be insulated from the structural deck members. In order to provide compatible aerial grounding systems and corrosion control systems, the following items shall be coordinated:

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

END OF CHAPTER 16.



Utah Transit Authority Light Rail Design Criteria

Chapter 17 Yard and Shop

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 17 YARD AND SHOP

17.1 General

Yard and shop design must allow for flexibility in LRV maintenance procedures. While overall operating and maintenance concepts are unlikely to change, the procedures shall evolve as maintenance personnel become familiar with the requirements of the LRVs and as the fleet grows through subsequent vehicle procurements.

17.2 Yard and Shop Facilities

Yard and shop facilities primarily serve the following functions:

- Storage for revenue vehicles, maintenance equipment and supplies
- Inspection, service and maintenance of revenue vehicles
- Repair of components removed from revenue vehicles
- Operator reporting and dispatch
- Miscellaneous maintenance and support services

The inspection, service and maintenance activities are discussed further in the following sections.

17.2.1 Daily Service

Daily service tasks are generally performed at night and include:

- Visual inspection of the running gear, lights and car body
- Interior cleaning
- Exterior cleaning

17.2.2 Running Repair

Running repair tasks generally require less than one shift (8 hours) to complete and do not require lifting of heavy components. Running repair may be performed on a two-shift or three-shift schedule. Running repair tasks would include:

- Minor repairs
- Scheduled inspections
- Component changeout
- Lubrication
- Testing

17.2.3 Heavy Repair

Heavy repair tasks are generally major repairs and overhauls, scheduled inspections and component change-outs that require more than one shift or require the use of vehicle hoists, cranes or other special machine tools to complete.

17.3 General Maintenance Philosophy

The goal of the maintenance program is to return the LRV to “ready for revenue service” status as quickly as possible. Those activities that by their nature prevent the LRV from returning to service until complete shall generally be performed on-site. Many maintenance procedures shall result in the exchange of good components (from shop stores) for defective components. The LRV can then be returned to service and the defective component repaired at a later time.

An important maintenance task shall be to conduct progressively more detailed inspections at regular mileage or service hour intervals as recommended by the vehicle manufacturer. Depending on the level of effort required, these inspections may be considered either running repair or heavy repair activities.

17.4 General Requirements

17.4.1 Operating Requirements

The maintenance facilities shall be suitable for the storage, servicing and maintenance of the LRV fleet.

17.4.2 Vehicle Criteria

The light rail vehicles (LRVs) shall have characteristics as specified in Chapter 11.

17.5 Yard

The yard is the point of dispatch for all mainline train service. Functions common to all yards include requirements for storage of trains, support of shops, sufficient lead trackage for making and breaking consists, and interior and exterior car washing.

The many diverse yard functions, plus the critical time factors directly preceding, during and after peak hour operations, necessitates a yard configuration that shall provide maximum train movement flexibility. Some important yard operations include:

- Insertion of trains into and removing trains from mainline service as required by the schedule in effect.
- Increase train car consists to meet peak hour requirements and then decrease train car consists for midday operation.
- Replace malfunctioning train with properly operating trains.
- Accommodate schedule adjustments if serious disruption occurs to mainline service.

17.5.1 Vehicle Storage

The yard shall provide for storage of the LRV fleet.

17.5.2 Yard Operations

Maximum flexibility is to be provided. Direct access from the mainline to the storage tracks is desirable. A run-around bypass track separate from the makeup and storage tracks is desirable for nightly servicing and movement of LRV's into and out of the shop.

Movements to and from storage, washing, etc. should require the least number of switching movements and still not block other movements. The yard should be structured so as to permit movements with a minimum of congestion.

17.5.3 Yard Layout

Basic guidelines for developing the yard layout are as follows:

- Direct access from the mainline to the storage tracks is required.
- A yard run-around track separate from make-up and storage tracks is desirable for nightly service, and access to shop tracks.
- Double ended storage tracks are desirable for maximum flexibility and to reduce revenue movements.
- A double throat lead track from the mainline to the storage yard is desirable because the simultaneous receiving and dispatching of trains is possible. Complete blockage of the throat during a turnout failure is eliminated.
- Minimum radius on yard tracks is 100 feet (car minimum turning radius is 82 feet).
- Loop track is desirable for maximum operational flexibility.
- Storage tracks shall be constructed to allow sufficient space for maintenance operations.
- Storage tracks shall ideally be sized to accommodate six light rail vehicles (common denominator for 2 and 3 car consists).
- Paved service aisles between storage tracks.
- Parking for personnel as close as possible to work areas in controlled areas.
- Space shall be provided as necessary for storage of miscellaneous materials and equipment.
- Yard lighting adequate for operations to be performed safely.
- Access roads to servicing yard and service aisles.
- Life safety requirement for emergency vehicle access to storage yard.

17.5.4 Yard Civil and Geometric Criteria

The following trackwork geometry criteria should be utilized as a guideline and must be coordinated with the vehicle specification.

Maximum slopes:

- Double ended storage areas (sag at midpoint, -0.5% max.) 0.0%
- Single ended storage areas (away from throat) 0.5%
- Inspection/Shop tracks 0.0%
- Minimum horizontal curvature (R) 100'
- Transition Curves not required
- Minimum track spacing:
 - Storage areas w/o aisles or OCS poles 12' absolute min.
 - Storage area w/OCS poles, w/out aisle 14' desirable min.

Storage areas w/aisles	16' absolute min.
Storage area w/service aisle	18' desirable min.
Throat area	14' absolute min.
Inspection and Shop tracks	25' absolute min.

An alternating system of track centers (i.e., 15' and 18') is recommended, where space is available.

- Minimum turnout size:

Lead-ins	#10
Yard Ladder Track	#6 desirable min. #4 absolute min.*
Main Line connection	#10

*Only to be used with written approval of the UTA Light Rail Project Director.

17.5.5 Yard Drainage

A complete drainage system shall be provided in accordance with the requirements of Chapter 5. Assuming sub-soil conditions and natural drainage are good, subgrade areas under trackwork should be topped with a six inch minimum layer of impervious material properly compacted and graded at a minimum slope of one in forty to the drainage system. Open areas and material storage areas should also be covered with a six-inch layer of impervious compactable material and graded to area drains.

The following drainage system elements, if required, should have minimum slopes of:

Subdrains	0.5%
Laterals	0.3%
Main Collectors	0.25%
Ditches	0.25%

Cleanouts should be provided at the terminus of each subdrain and lateral, and manholes should be provided at maximum intervals of 200 feet on the laterals and main collectors in order to facilitate the maintenance of the yard drainage system. The individual subdrain runs should not be longer than 200 feet.

17.6 Vehicle Maintenance Functions

The shop shall be an all-purpose facility designed to facilitate the performance of scheduled inspection, minor or running repairs, and interior and exterior car cleaning. The shop layout shall be designed to separate work functions so that transit cars may be inspected, serviced and returned to revenue operation as quickly as possible. The vehicle fleet can be serviced by a shop with two run through tracks and six work positions. The shop layout shall be designed not to preclude expansion to service a forty vehicle fleet.

17.6.1 Daily Safety Inspection

Each train shall be subjected to a departure safety test before it is dispatched into revenue service. The departure test is to be performed prior to each such dispatch to verify that all major operating equipment, including control equipment, is in satisfactory condition.

The departure test should be made on a yard lead track to the main line or on the storage track and should include such verification and operation tests as can be made properly on traction systems under operating conditions.

17.6.2 Daily Interior Car Cleaning

Cars which have been in revenue service require inside cleaning or sweeping daily. Trash shall be removed, light stains or spills cleaned, and graffiti shall be removed using non-toxic and non-flammable materials whenever possible. These functions shall be performed in the storage yard or at a designated location on the wash or sanding track.

17.6.3 Heavy Interior Cleaning

Heavy cleaning shall be accomplished as the car is scheduled for shop inspections. A servicing platform is required for these purposes. The servicing platform shall consist of a cleaning bay with step level platforms along both sides located on the wash track between the wash and rinse cycles. A portable wet vacuuming system is desirable for ease of washing the floors, walls and mats on the vehicle.

17.6.4 Exterior Car Cleaning

Car exteriors shall normally be washed daily. An enclosed car wash is required to facilitate this service. Current storm water pollution prevention regulation prohibits any discharges that may impact storm water or violate permits held by UTA.

The best location for exterior car washers is off the inbound tracks so that trains can be washed as they come in for laying-up. The facility should have a prewash spray, adequate chemical storage and mixing facilities. The automatic wash should also be capable of cleaning the front and rear of the car. Special efforts shall be necessary to remove graffiti from the cars. Emergency eyewash and shower facilities are required in areas where chemicals are used as part of the daily work activities. Building areas should be suitably heated and ventilated. A self-contained, enclosed pit with steam cleaning facilities should be provided to clean car underbody components.

The catenary system should be continuous through the car wash in order to power the trains through the building. Speed can be controlled manually by using a wayside sensing system and traffic lights similar to those used on bus washers. The vehicles should be equipped with a wash mode to limit the speed to 1½ miles per hour.

To reduce water consumption, a suitable water reclaiming unit shall reclaim a high proportion of the rinse water. Provision must be made to remove sludge and neutralize all effluent discharged into city sewers.

Installation of high-velocity air scrubbers is required to minimize the possibility of the final rinse water freezing on the cars in cold weather. Normally, cars shall be returned to storage after washing. In cold weather, it may be necessary to hold the cars in the cleaning bay for a period of time to allow excess moisture to drip off and avoid freezing of doors and steps. The ends of cars facing each other in trains do

not lend themselves to automatic cleaning by machines. These ends shall have to be cleaned by hand after passing through the wash machine.

17.6.4.1 Configuration of Work Area

- Support the requirements of the washer
- Area between wash and rinse shall be equipped with vehicle step height platforms to provide an area to perform heavy interior cleaning and daily cleaning
- Area between wash and rinse shall contain a pit between the rails to allow underbody steam cleaning

17.6.4.2 Utility Requirements

- Support the requirements of the washer
- Overhead lighting
- 120/220 V receptacles
- Recycle equipment to meet local codes
- 750 V DC catenary through the building
- Area floor drainage
- Hose bibs
- Compressed air
- Pit lighting

17.6.4.3 Special Equipment

- Package train washer complete with all recycle and chemical equipment
- Steam generator

17.6.4.4 Design Requirements

- Locate on a through track with good access to storage yard
- Sanding operation may be on same track as train washer, but not in the wash and rinse areas
- Isolation of electrical systems

17.6.5 Maintenance Inspection

At scheduled intervals, each vehicle shall receive a thorough inspection of all systems. Inspection bays shall be provided to handle inspections. The inspection bays can also be used for minor repair work on the control, brake, and other systems.

Pits shall allow inspection of trucks, couplings, draft gear and equipment under the car; portable steps shall allow good access to equipment boxes and-car steps under the side of the car; moveable platforms shall be provided for access into the cars from the pit, and high level platforms are positioned for pantograph inspections.

As part of the inspection, lubricant levels shall be checked. Lubrication equipment shall allow topping-up lubricants as required.

Portable cables shall provide 750 V DC power to the car. This shall allow operation of the car auxiliaries while isolating the pantograph from the high voltage power. Isolating switches shall also allow disconnecting the traction power contact wire through the inspection bays.

17.6.5.1 Configuration of Floor and Work Space

- Rail mounted on pedestals
- Continuous pits 4 to 5 feet deep with utility services listed below
- Pantograph inspection and vehicle roof access platforms
- Vehicle floor/step entry level platforms
- Ramps or material lift and steps from rail level aisles to pit floor

17.6.5.2 Utility Requirements

- Compressed air
- Area floor drainage
- Area overhead lighting to provide 35 to 45 foot-candles, at all work locations
- Pit and platform lighting
- 120 V receptacles available at all work levels
- Catenary through the building w/isolation switches
- 750 V DC power and portable cable
- Extra large high pressure hose bib for shop housekeeping

17.6.5.3 Special Equipment

- Eye wash (throw away type recommended)
- Portable step platforms

17.6.5.4 Design Requirements

- Should be on through tracks

17.6.6 Minor (Running) Repairs

The inspection process may turn up defects in the various subsystems on the cars. Where possible, these defects shall be corrected in the inspection bay or minor repair area by replacement of components. As an example: an improper function in the propulsion subsystem may be repaired by replacement of a faulty electronic circuit card.

Repairs in these bays shall be limited to those which are simple and can be accomplished in a few hours so that the tracks are not tied up longer than 4 hours. Where the repair problem requires a longer period or special equipment, the repair shall be scheduled and the individual car moved to the appropriate repair track equipped with the required equipment.

17.6.7 Major Repairs and Component Change Out

Major repairs include heavy repairs such as truck repair, overhauls, renovating undercar structures, refurbishing interiors, etc. These repairs are scheduled and a computerized management information system has been established to maintain records of maintenance performed on each car. These repairs normally take an extended period of time.

17.6.7.1 Configuration of Floor and Work Space

- Floor at top-of-rail elevation, except at LRV hoist equipment pits
- Covered LRV hoist equipment pits per hoist equipment manufacturer's requirements
- Sufficient clear space beside work positions to bring a forklift under a raised LRV to remove equipment
- Portable scaffolding to reach roof equipment

17.6.7.2 Utility Requirements

- Overhead lighting to provide 35 to 45 foot-candles at all work locations
- 110/220 V receptacles
- Compressed air
- Pit and area floor drainage
- Hose bib
- Equipment services
- DC power for LRV auxiliary equipment

17.6.7.3 Special Equipment

- LRV hoist equipment
- Jib crane to remove roof equipment
- Truck transfer and turntable

17.6.7.4 Design Requirements

- Should have access to wheel truing area

17.6.8 Wheel Truing

Periodically, flat spots on wheels must be removed and the rims and flanges restored to correct profile. This task is accomplished by a wheel truing machine—an underfloor wheel lathe or milling machine with the added capability of resurfacing the brake discs.

17.6.8.1 Configuration of Floor and Work Space

- Floor at top-of-rail elevation except at machine pit
- Two level pit per manufacturer's requirements
- Floor grating at shallow pit (control station) level

- Wheel truing shop enclosed area sufficiently large to close the shop doors with any LRV axle over the machine

17.6.8.2 Utility Requirements

- Overhead lighting to provide 35 to 45 foot-candles at all work locations and 20 foot candles for safety lighting
- Pit lighting
- 110 V receptacles
- Compressed air
- Pit and area floor drainage
- Hose bib
- Wheel truing machine utility services
- Contact wire interlocked with machine power

17.6.8.3 Special Equipment

- Underfloor wheel truing machine
- Chip removal system

17.6.8.4 Design Requirements

- Should be accessible from truck shop
- Can be on same through track as heavy repair

17.6.9 Vehicle Body Repairs

The amount of vehicle body work shall depend upon the accident rate and severity of accidents encountered by the fleet. Minor damage can be repaired by mechanics using replacement panels and body patches. Heavy damage repairs may be contracted out to others.

17.6.9.1 Configuration of Work Area for Minor Damage Repairs

- Floor at rail height
- Floor area adjacent to rails shall support the use of portable jacks and car body stands

17.6.9.2 Utility Requirements

- Compressed air
- Overhead lighting to provide 35 to 45 foot-candles at work locations
- Welding machine outlets
- 120/220 V receptacles
- Hose bib for shop housekeeping

17.6.9.3 Special Equipment

- Portable jacks
- Portable body stands
- Portable welding machine
- Portable acetylene/oxygen cut-off unit
- Power tools

17.6.9.4 Design Requirements

- Should be near/or adjacent to the crane and tool shed

17.6.10 Vehicle Painting

Initially the requirements for painting shall depend on the type and material of the vehicle chosen, and upon the accident rate and severity of accidents. With the exception of minor hand painting, all car body painting may be done at existing UTA facilities.

17.6.11 Vehicle Sanding

The sanding facility should be located in the normal flow of traffic from the main tracks to the storage tracks, or from the storage tracks to the train washer.

17.6.11.1 Configuration of Work Area

- Floor area should be at rail height
- Area should be fully enclosed
- Pit between tracks

17.6.11.2 Utility Requirements

- Support sanding system requirements
- Overhead lighting
- 750 V DC catenary through operation
- Area drainage with sand traps
- Pit lighting
- 110/220 V receptacle

17.6.11.3 Special Equipment

- Sand receiving track and/or truck delivery road
- Pneumatic sanding system consisting of:
 - Receiving tank—24 ton capacity
 - Transfer tank
 - Elevated delivery tanks

- Associated piping and controls
- Automatic shut-off nozzle for each drop

17.6.11.4 Design Requirements

- Should be easily accessible from storage tracks and in the normal traffic flow to the train washer and inbound inspection
- Should be configured to sand four vehicle storage boxes in one stop
- Should have anti-freeze heating

17.6.12 Shop Ancillary Areas

The following provides a description of the functions of the shop ancillary areas required for operation of the system.

- Foreman's Office
- Operator Reporting & Dispatch
- Fare Inspector Reporting and Dispatch
- Rail Operations Center
- Operators Ready Room
- Operators Quiet Room
- Vending Machines & Kitchenette
- Transportation Locker Rooms & Toilets
- General Office
- Office – AGM Rail Operations
- Office – Superintendent Rail Transportation

17.6.12.1 Utility Requirements

- Overhead lighting
- 120 VAC receptacles
- Telephone lines
- Potable water
- LN gas for water heaters

17.6.13 Operations and Control Area

The operation of the yard and mainline shall be supervised from a location in the shop building. This facility shall provide:

- Operations and control of revenue consists
- Communications equipment tied into the bus communications network for communicating with train operators, track maintenance crews and other operations personnel
- Yard operations and control

17.6.13.1 Utility Requirements

- Uninterruptible Power Supply (UPS) consisting of an inverter, static switch, AC bypass transformer and manual bypass switch of sufficient rating to meet communication needs.
- Generator back-up power for essential loads in the Control Rooms.
- 120 VAC power for communication needs not met by UPS.

17.6.14 Emergency System Requirements

17.6.14.1 Safety Systems

- Fire Alarm System
- Door Control
- Essential power receptacles
- Grounding

17.6.14.2 Utility Needs

- Eye wash station water and drainage
- UPS power
- Generator back-up power for 480VAC and 120Vac essential loads
- Essential lighting including exit signage
- Sprinkler system water
- Diesel fuel with day tank

17.6.15 Building Systems

- Telephone System
- Computer network
- HVAC
- PA System

17.6.15.1 Utility needs

- Telephone lines
- Electrical 12.46 KV power
- LN gas

END OF CHAPTER 17.



Utah Transit Authority Light Rail Design Criteria

Chapter 18 Rail Trails

Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 18 RAIL TRAILS

18.1 General

This chapter describes the functional design requirements, and the interface criteria with other work, for trails, which may be proposed adjacent to railroad tracks. This criteria provides guidance for application to multi-use trails, including pedestrian and bicycle trails. All motorized vehicles, including motorized bicycles (“mopeds”) are prohibited. All horses are also prohibited in active light rail corridors.

This chapter applies to all railroad property. Trail planning in rail corridors not yet fully developed or fully engineered for transit shall be master planned to not restrict station location (see Figure 18-1).

Any Rail Trails applicant must be prepared for and must accommodate a demanding design development process. Because of the large variety of issues that must be coordinated, the way ideas develop and are explored, and the proposed design elements may have complex interrelation to future transit use of the property, UTA may, at any time, deny what seemed to be an acceptable design concept at the inception and require that the designer seek alternate concepts or require that the property not be used for some purpose which has been the subject of investigation. The trail development proposal shall be submitted to the UTA Asset Management and Business Development Department. All communications shall be submitted in writing. All proposals are subject to preliminary review by the UTA Development Review Committee (DRC) comprised of key UTA staff responsible for the development, operation, maintenance, and preservation of UTA property assets. The DRC may make recommendations to UTA’s Deputy Chief of Asset Management and Business Development who is UTA’s authorized agent for final approval/disapproval.

Each application shall include six copies of the items bulleted below including one original containing signatures of approval by an authorized agent from UDOT and an authorized representative from the Engineering Department of any local jurisdiction prior to submittal for review by UTA.

- Project description
- Area Map
- Site plans
- Sections
- Other drawings as may be required for adequate review
- Drainage design report (as applicable)
- Grade crossing safety report
- Trail maintenance plan
- Construction management plan

Project Descriptions shall include the proposed functional use of the trail, all proposed modal uses (bicycle, pedestrian, etc.) and restrictions, and any additional explanations pertinent to the trail proposal.

Area Maps shall be included in the engineering drawings at an appropriate scale to identify the entire area of the UTA property to be encumbered.

Site plans for development of the trail need to include all proposed uses but also must include existing details of the rail corridor, including:

- property boundaries (illustrating the entire width of the railroad rights-of-way),
- existing fencing
- roadway limits at all crossings or frontages,
- existing topography (2 foot contours)
- all existing drainage facilities,
- existing track work,
- existing signals,
- existing catenary equipment,
- existing bridges,
- existing public utilities
- building footprints within 10'
- other items as necessary to ensure that the trail plan is incorporated with the whole railroad corridor function.

Typical drawings shall be at 1:50 engineering scale, English units on 11×17 media. An engineer registered in the State of Utah must seal final plans and reports for the trail design.

Sections shall include typical sections as well as other sections as may be required for adequate review. Additional sections will be required to illustrate situations such as: railroad cuts or steep grades, severe terrain, existing or proposed separation grade crossings, narrow corridor widths, etc.

Other drawings may be required for adequate review such as grading and drainage plans, signage plans, lighting plans, striping plans, etc.

The Drainage Design Report shall include a detailed statement summarizing all material impacts of the proposed trail to the storm water runoff within the right of way. The summary should identify how surface water will be managed, including cross flow, and how the tracks within the right of way will be protected (UTA may provide to the extent possible any as-built drawings or similar material showing the existing storm water runoff system). A particular objective of surface water management is to protect ballast from being fouled (i.e. silt carried by runoff).

A Water Pollution Prevention Plan shall be developed in accordance with the provisions of the Memorandum of Understanding (MOU) between UDOT and the Utah Department of Environmental Quality and the Best Management Practices (BMP) plans and approved by the Utah Division of Water Quality.

A Grade Crossing Safety Report shall be completed including a hazard/risk analysis prepared and signed by a professionally-certified safety engineer (or other risk management or safety professional acceptable to UTA) and shall be provided to UTA. This report shall address all aspects of safety issues including potential vulnerabilities of a trail proposal if applicable. It shall include but not be limited to analysis of pedestrian protection design at roadway crossings paying particular attention to mid-block roadway crossing conditions and trail user behaviors.

Trail Maintenance Plan shall include description of the applicant's intent for maintenance of the affected corridor should the encroachment be approved. The plan shall include, but not be limited to, how roadway barriers at crossings may be cleared and reinstalled as part of emergency, major trail repair, or railroad maintenance access. It shall include the maintenance intent of the trail owner and shall demonstrate a comprehensive responsibility for development within the UTA railroad corridor.

Construction Management Plan shall include construction safety plans for work performed in the right of way as outlined as part of the Roadway Worker Protection Safety Program Manual. The construction management plan will outline how the contractor and its subcontractors will protect the rail bed from water cross flow and potential sediment contamination of rail beds. The construction management plan will specify the organizational structure of how the day to day work will be managed consistently for the duration of the project. Refraining from shuffling of key personnel involved in the onsite management of the day to day work is essential to the success of the project.

The Construction Management Plan will address such items as: Job Layout, Personnel and Subcontractor Personnel Information, Accident Prevention Responsibility, Job Site Safety and Sanitation, Traffic Control, Public Protection, Site Cleanup, Construction Equipment and Material Storage, Fire Protection, Gasoline and Fuel Oil Management, and Employee parking.

18.2 Project Implementation

A General License Agreement between UTA and the applicant or sponsor demonstrating financial responsibility for the trail must be completed prior to construction of an approved trail project. The licensee and its contractors shall enter into Right of Entry agreements prior to entrance onto UTA property for any reason.

The Contractor Right of Entry Agreement for construction of the project cannot be completed until completion of the General License Agreement and full approval of design has occurred. All construction workers shall receive Railroad Roadway Worker Protection Training by UTA and subsequently comply with all applicable regulations. The contractor will be required to demonstrate adequate insurance protection. *Insurance exclusion for railroads and explosion, collapse and underground hazard shall be removed from the required policy prior to acceptance by UTA.*

18.3 Site Work

This section provides minimum design standards for trail development within UTA railroad corridors; however, each trail plan will be reviewed for its site-specific conditions and may warrant more conservative design requirements.

18.3.1 Setback

Technical factors effecting setback include: type, speed and frequency of current or master planned trains in the corridor, separation technique, topography, sight distance, maintenance requirements, etc. UTA's standard for trail setback is 25 feet from centerline of the nearest existing and/or planned track (see Figure 18-1). Exceptions may exist in constrained corridor areas to allow for 15–25 feet of setback when additional separation measures can be implemented such as existing and/or planned slower and reduced frequency train operation, solid barriers, vertical separation, and other added safety measures. Such variances will be reviewed on a case by case basis. Additional setback may be required where railroad cut or high grade conditions exist and/or are planned.

18.3.2 Fencing

The trail shall be separated from the track with a 42" minimum fence height or as required by applicable state and federal regulations whatever more stringent, except in approved locations where trail is directly adjacent to station platform. Trails, which will serve as bike paths, shall be designed in accordance with the current AASHTO Guide for the Development of Bicycle Facilities in regard to fencing and guardrails.

Fencing materials may be required to match fencing specifications found elsewhere within the UTA corridor. Fencing specifications shall comply with local code and zoning regulations. All fencing shall allow for through visibility and line of sight safety.

The separation fence shall be placed away from the edge of the trail in compliance with AASHTO regulations. However, separation fencing shall be placed as close to the trail as allowed by applicable regulations to maximize the setback of the fence from the centerline of the nearest railroad track work (see Figure 18-1).

Where fencing is to be placed adjacent to signal cabinets, a minimum 4' clearance is required around the cabinet to allow signal maintenance personnel clear access to this equipment.

18.3.3 Trail Surface

The trail surface shall be a minimum of 10 feet wide. The trail surface shall include a sub grade consisting of 6" (inches) of untreated road base compacted to 96% density, and 3" of compacted asphalt with a maximum aggregate size of 1/2". Soil sterilant shall be applied on top of road base and below asphalt to limit sterilant migration.

Longitudinal grade of the trail shall be a maximum of 4%. Preferred maximum cross slope is 2% and shall slope in one direction, crowning is not acceptable. See 18.3.4 for additional slope requirements.

The profile of the path shall generally follow the existing ground surface and the track profile to avoid large cross grade differentials. The surface shall be smooth and free of potholes, and uniform along the pavement edge.

Where conditions require construction of retaining walls to retain slopes, the walls shall be constructed on the trail side of the separation fence.

The trail surface shall meet the current applicable requirements of the ADA.

Trails, which will serve as bike paths, shall be designed in accordance with the current AASHTO Guide for the Development of Bicycle Facilities in regard to design speed, horizontal and vertical alignment, grades, and stopping sight distances.

18.3.4 Drainage

Maintaining the integrity of the railroad drainage system is of paramount importance. Trail drainage shall be properly designed to avoid impact to the railroad track or overloading of the track area drainage system or other systems within the corridor.

Wherever possible, the trail shall be designed to drain away from the track. A 2% cross slope is required on all trail surfaces. The trail shall slope in one direction; crowning is not acceptable.

Drainage shall be by gravity flow.

No sanitary sewer discharge shall be permitted to enter any drainage system.

18.3.4.1 Design Method

- All storm water facilities draining 5 acres or less shall be designed for the maximum expected discharge, determined by the Rational Method.
- All storm water facilities draining more than 5 acres shall be designed for the maximum expected discharge, determined by using the United States Soil Conservation Method.
- Storm facilities shall be designed in accordance with local jurisdictional requirements.
- Drainage structures shall be selected from County Standard plans.

18.3.4.2 Storm Frequency

The facilities shall be designed/protected by accommodating a 30-minute duration 10-year storm frequency.

18.3.4.3 Storm Water Management and Sediment Control

Where construction activities shall disturb five or more acres of land, the design shall comply with the Utah Pollutant Discharge Elimination System (UPDES) Permit Requirements, as regulated by the State of Utah, Department of Environmental Quality, Division of Water Quality (DWQ). At a minimum, erosion and sediment control plans shall be in accordance with International Building Code (IBC) and the Wastewater Disposal Regulations Part II, Standards of Quality for Water of the State (distributed by the DWQ).

18.3.4.4 Drainage Grates and Manhole Covers

Drainage inlet grates, manhole covers, etc., on bikeways should be designed and installed in a manner that provides an adequate surface for bicyclists. They should be maintained flush with the surface when resurfacing.

Drainage inlet grates on bikeways shall have openings narrow enough and short enough to assure bicycle tires will not drop into the grates, regardless of the direction of bicycle travel.

Driveway construction should avoid construction of a vertical lip from the driveway to the gutter, as the lip may create a problem for bicyclists when entering from the edge of the roadway at a flat angle. If a lip is deemed necessary, the height should be limited to $\frac{5}{8}$ inch.

18.3.5 Landscaping

Landscaping for the trail shall be designed in accordance with crime prevention through environmental design, property protection and aesthetic objectives.

- Do not create hiding places by use of high and/or thick vegetation.
- Do not introduce invasive species into the railroad corridor, which have the potential of obstructing the maintenance or drainage of the track structure, or cause damage to the trail surface.
- Do not introduce trees adjacent to the railroad corridor, which have the potential of encroaching on the track and catenary envelope.
- Use low maintenance drought tolerant landscaping. Do not use irrigation systems.
- The landscape design should be compatible with the local and regional aesthetic character adjacent to the trail.

- The landscape design should establish visual identity through consistent use of a few basic construction elements and plant materials, where required, while maintaining interest and compatibility with adjacent areas through the use of other materials that vary from site to site.
- Protect existing views and vistas.
- Protect existing plant materials as appropriate, particularly mature trees, and replace such material, which must be removed during construction.
- Coordinate grading required for landscape design with overall site grading requirements.

Recommended lists of low water use plants are available in the Landscaping Chapter of the UTA Design Criteria Manual.

The design plans shall include a landscaping plan detailing the planting locations and ultimate size of the plants to demonstrate their relationship to the trail and the track.

18.3.6 Lighting

Lighting is not a standard requirement for trails along UTA corridors. Lighting requirements will be considered on a case-by-case basis. Any sections of the trail historically prone to vandalism, areas with inhibited visibility such as under bridges or in tunnels, or where heavy night use is expected require lighting considerations. AASHTO light level recommendations shall be considered for minimums.

18.3.7 Signs

Standard UTA “No Trespassing” signs shall be installed at the separation fence within 50 feet of each track grade crossing and at a maximum spacing of 500 feet along the separation fence (See Figure 18-2).

Other signs required for control of trail traffic, track grade crossing control, or highway grade crossing control shall be designed in conformance with the Manual of Uniform Traffic Control Devices (MUTCD).

Sign description and locations shall be included on the design plans.

Other signage may be required by UTA.

18.3.8 Striping

A yellow centerline stripe may be used to separate opposing directions of travel. A centerline stripe will be used in the following circumstances:

- a. Where there is heavy use;
- b. On curves with restricted sight distance; and,
- c. Where the path is unlighted and nighttime use is expected.

18.3.9 Roadway Interface Features

A physical feature must be included at each roadway approach that requires a bicyclist or equestrian to dismount before proceeding into the public right of way. Non compatible modes of transportation must have separate Entrance/Exit devices and must be placed in advance of reaching common areas. Each device utilized shall restrict motorized vehicle access but allow emergency and maintenance vehicle access. Devices shall be easily restored to restrict motorized vehicle access upon termination of emergency or maintenance vehicle access. When locating such installations, care should be taken to assure that each device is well-marked and visible, day or night (i.e., install reflectors or reflectorized tape).

Striping near each Entrance/Exit device is recommended. If sight distance is limited, special advance warning signs or painted pavement warnings should be provided. Barriers should permit passage of bicycle-towed trailers, adult tricycles, and assure adequate room for safe accessible passage.

18.3.10 Restroom Facilities

Trail design plans must indicate locations of any public restrooms existing in the area or proposed for construction as part of the project, which will be available to trail users.

18.4 Crossings

Crossings shall be limited. When crossing of the track by the trail is necessary, use of existing crossings or grade separation structures is required. The risk is kept to a minimum where the trail crosses the tracks at a 90 degree angle. Trails users may use existing sidewalks that cross within public ways where appropriate warning devices and approach angles exist. If new at-grade crossings of the track are proposed, approval must be obtained from all affected governing agencies, including UTA and UDOT.

Trail crossings of streets and highways require the approval of the governing agencies having jurisdiction over the development of the roadway. Wherever possible the trail should make use of existing signalized pedestrian crossings. New trail/roadway crossings required signing, striping, and signalization in compliance with AASHTO and MUTCD. Trail intersections and approaches should be on relatively flat grades. Stopping sight distances at intersections should be checked and adequate warning should be given to permit bicyclists to stop before reaching the intersection, especially on downgrades.

If a trail crossing of a roadway is proposed adjacent to an existing roadway/rail grade crossing, the design plans must address any modifications that will be required to the existing grade crossing warning devices, stop bars, signal, curbs, and traffic islands to adequately warn trail users. The signal plans for the crossings must identify interlocking requirements between the pedestrian crossing signals and the railroad signal system to prevent queuing of cars on the tracks during pedestrian crossing of the roadway. Any additions of or changes to the railroads signal or active crossing warning system will be designed and installed by the entity having jurisdiction, at the project's expense.

Figure 18-1: Rail Corridor Typical Section for Rail Trail Planning

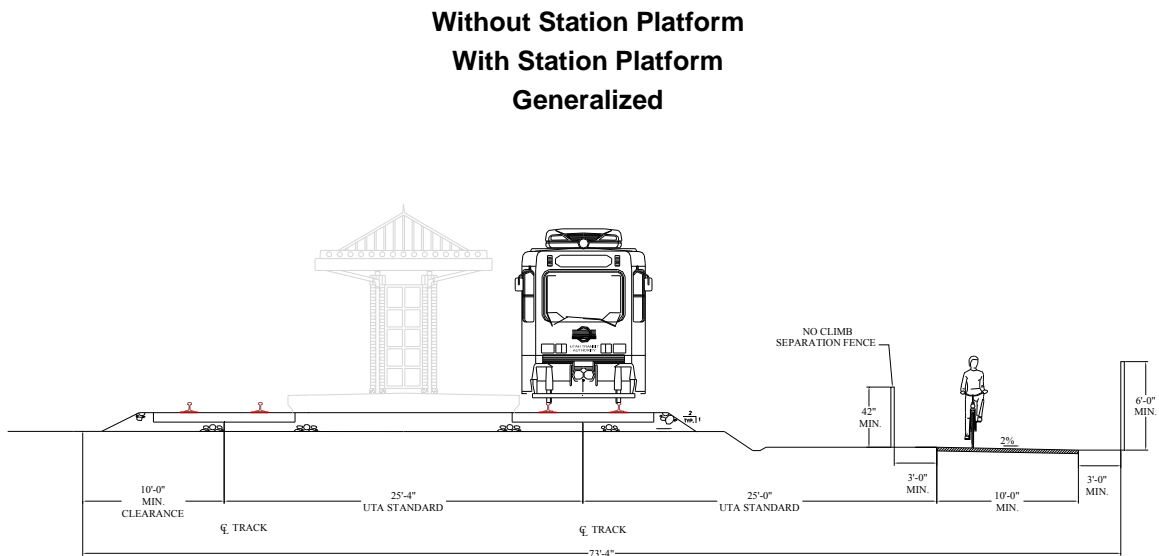
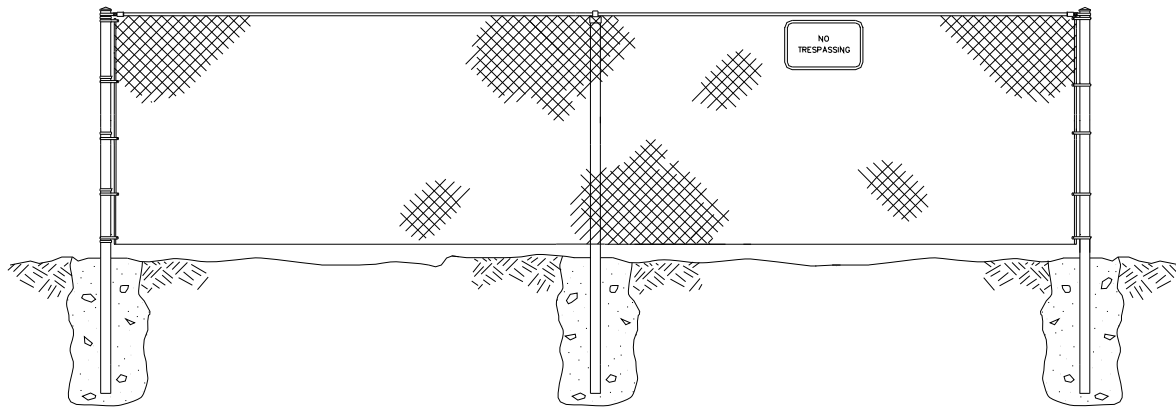


Figure 18-2: No Trespassing Signs



END OF CHAPTER 18.



Utah Transit Authority Light Rail Design Criteria

Chapter 19 Pedestrian Crossings Revision 4, November 2007

Design Criteria UTA Light Rail				
Rev No.	Prepared By	Approved By	Approval Date	Document Date
0				1997
1				Oct. 2001
2				Sep. 2002
3				Jul. 2006
4	JWebb	CMT CCC	11/20/07 11/30/07	11/30/07

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CHAPTER 19 PEDESTRIAN CROSSINGS

19.1 GENERAL

The pedestrian crossings chapter provides guidelines and drawing details for the application of pedestrian treatments and its interface with other elements in the UTA light rail projects.

Light rail systems differ from commuter or freight trains where they encounter pedestrians. The differences include:

- Light rail vehicle crossings are more frequent than freight crossings. Headways for LRVs are typically 15 minutes or less.
- LRVs are much quieter than freight trains.
- LRVs have shorter stopping distances.
- High pedestrian traffic crosses the tracks at stations.

The design guidelines for light rail pedestrian crossings ensure a higher level of safety for pedestrians and give guidance to planners, designers, and managers. The design criteria set safety standards consistent throughout the UTA system.

19.2 DESIGN INTENTIONS

The general design approach, to reduce pedestrian safety hazards, proceeds as follows:

- Eliminate hazards
 - Eliminate pedestrian sight distance deficiencies if possible.

When it is not possible to eliminate hazards take measures to lower the risk to pedestrians:

- Mitigate unavoidable hazards.
- Provide a higher level of safety treatments and justify why hazards can not be eliminated or mitigated.

19.3 IMPLEMENTATION

The provisions of the design guidelines for Light Rail Pedestrian Crossings apply to:

- New projects
- Upgrades to the existing system

19.3.1 Existing System

Retroactive application is not required by these guidelines. The existing system may be brought into compliance as future improvement projects are implemented that upgrade the existing crossings.

19.4 DEFINITIONS

A semi-exclusive use, light rail operating environment is in a separate right-of-way, or along a railroad right-of-way where motorists, pedestrians, and bicyclists cross only at designated points. An example is on the North-South line south of 1300 South.

A mixed use, light rail operating environment is in mixed traffic that shares access with motorists, pedestrians, and bicyclists such as city streets. An example is along Main Street in Salt Lake City.

19.5 STANDARDS

The section describes pedestrian treatments used to improve pedestrian safety in various circumstances along the light rail corridor.

Standardized treatments create better understanding for patrons and the general public resulting in reduced safety risks. UTA standards allow for the following pedestrian treatments:

19.5.1 Passive Safety Treatments

19.5.1.1 “Cross only at Crosswalks” Pavement Markings

Apply this treatment:

- Where there is a mixed use environment, and
- At light rail platforms.

19.5.1.2 “Stop For Trains” Pavement Markings

Usually not required in a mixed use environment due to intersections that are controlled by traffic signals.

Consider this treatment at locations where:

- Light rail vehicle are in a semi-exclusive right-of-way.
- Location of stopping point is unclear to pedestrians.

19.5.1.3 Tactile Warning

Apply this treatment:

- Where there is semi-exclusive right-of-ways for the LRVs,
- Where detectable warning is required at light rail station platforms,

- In a mixed use setting, extend the tactile warning beyond the station platform and into the crosswalk.

19.5.1.4 “Look Both Ways” Signage

Install this signage where:

- Light rail vehicles are in a semi-exclusive right-of-way, and
- At light rail platforms using ballasted trackway

19.5.1.5 Channeling

Consider channeling where:

- Pedestrians will likely cross the track in an unauthorized location, and
- Channeling will minimize risky pedestrian behavior.

19.5.1.5.1 Z Crossings

Use Z crossing channeling only where:

- Adequate sight distance exists.
- There is a semi-exclusive right-of-way.
- There is no dual direction single track usage.

19.5.1.6 Pedestrian Barriers

Consider barriers where:

- A high likelihood exists that pedestrians will cross the tracks in a hurried manner, and
- Channeling prevents pedestrians from bypassing the barriers.
- There is limited sight distance.

19.5.1.7 Swing Gates

Consider swing gates at locations where:

- A high likelihood exists that pedestrians will cross the tracks in a hurried manner, and
- Channeling or barriers prevents pedestrians from bypassing the swing gates,
- There is limited sight distance,
- Acceptable provisions are provided to allow the disabled to open the gates.

19.5.2 ACTIVE SAFETY TREATMENTS

19.5.2.1 Pedestrian flashing lights and audible warning device

Use this device in a train control signal environment. Use in conjunction with a crossing that has automatic vehicle crossing gates, lights, and bells. Apply treatment where:

- LRVs operate in a semi-exclusive right-of-way, and
- Sight distance considerations and/or school zones warrant its use.
- Area conditions hinder effectiveness of standard vehicle gates, lights, and bells.

19.5.2.2 Gates crossing sidewalk (vehicle or pedestrian)

Place automatic vehicle gates behind sidewalks when possible. Use automatic pedestrian gates only when severe hazards cannot be eliminated by other means. Conditions for use of this treatment include:

- LRVs operate in a semi-exclusive right-of-way, and
- Pedestrian sight distance is severely restricted, and/or
- School zones are present, and/or
- Nearside stations are nearby, and
- A safe refuge area between the gates and the LRV dynamic envelope can be provided.

19.5.2.3 LRV-activated LRT visual/audio warning

Use this device in a traffic signal controlled environment. This device is intended to provide a supplemental warning to pedestrians that a train is approaching.

Proper applications may include:

- LRVs operate in a mixed use setting, and
- The pedestrian crossing is an unsignalized mid block crossing or is at a traffic signal controlled intersection adjacent to a platform.

19.6 SAFETY ANALYSIS

Due to the varied light rail operating environments and conditions, a diagnostic team will analyze each pedestrian light rail crossing location. Safety factors that mitigate or warn of hazards will be selected based on these guidelines and consideration of all factors for each location.

19.7 APPLICATION OF SAFETY TREATMENTS

Table 19.7.3 and figures 19.7.1.1 through 19.7.1.4 show the application of the various safety treatments.

19.7.1 Safety treatment warrants

Various conditions are present at pedestrian crossings. Pedestrian crossing warrants help determine the types of pedestrian treatments. The classification of pedestrian crossings and implementation of treatments raises the safety awareness level of those who plan, design, construct, and operate the system. The classifications to consider are as follows:

19.7.1.1 Environment

LRT passengers (pedestrians) at station areas know they are in a railway environment. Pedestrians in this environment have a heightened awareness aiding their safety.

Non-station LRV environments generally occur at pedestrian crossings that are used by the general public for purposes unrelated to the LRT system. Pedestrians in a non-station environment need additional pedestrian treatments due to the sudden transition from sidewalk safety to railway dangers.

19.7.1.2 Sight distance

Sight distance is a critical criterion that determines pedestrian safety treatments. Placement of landscaping, cabinets, bungalows, walls, etc near crossings and platforms affect sight distance. Designers will show that sight distance is adequate, limited, or severe from the accepted sight zone triangle illustrations shown in figure 19.7.1.3.1 and 19.7.1.3.2

19.7.1.3 High pedestrian activity

High pedestrian activity is another warrant for pedestrian treatments. Locations with 60 pedestrian crossings during each of any two hours in a day are considered high pedestrian activity areas.

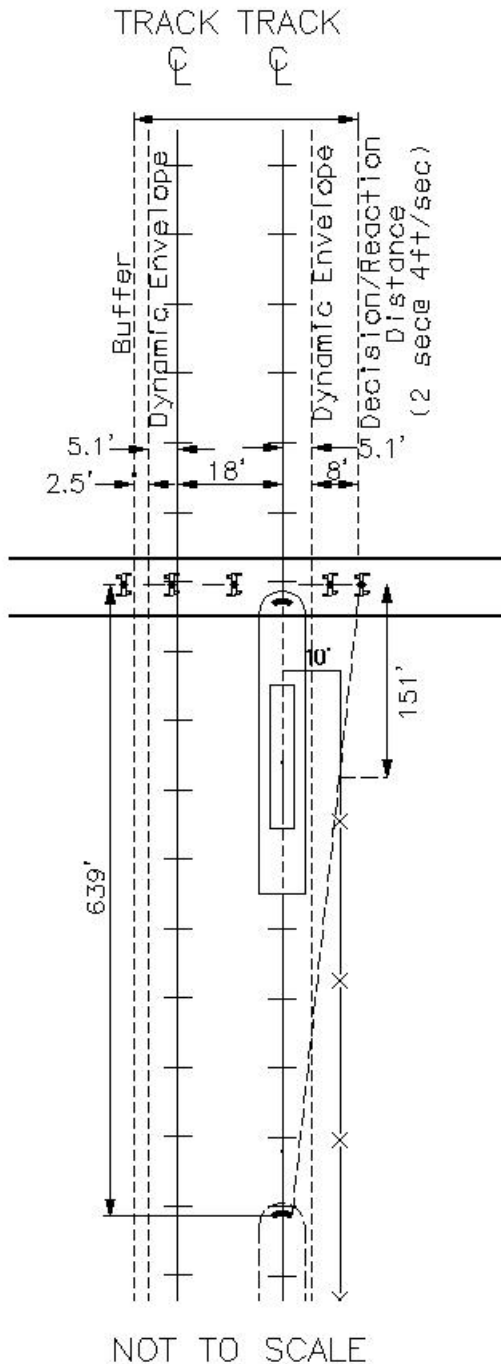
19.7.1.4 School zones and routes

School zones and routes are another factor that merits special consideration for pedestrian treatment. Roadway sign designations and discussions with the school district determine what constitutes a school zone or route.

19.7.1.5 Near Side Stations

Near side stations are a unique condition warranting pedestrian treatments. Pedestrian grade crossings with access just beyond oncoming LRV stations are a unique situation requiring some form of treatment.

FIGURE 19.7.1.2.1



Example on how to determine placement of object to achieve proper sight distance

Assumptions:

LRV is traveling from the bottom to the top on the right hand track.

Pedestrian walking speed = 4 ft/sec with less than 20% elderly population.

Time for pedestrian to cross track = 38.7ft / 4ft/s = 9.67 seconds.

Fence is 10' from track centerline

Minimum Crossing Distance, 38.7 feet where:

8' is the distance traveled at 4 feet per second during the decision/reaction time of 2 seconds.

5.1' is the distance from the centerline of track to the outer edge of the dynamic envelope.

18' is the distance between the two track centerlines.

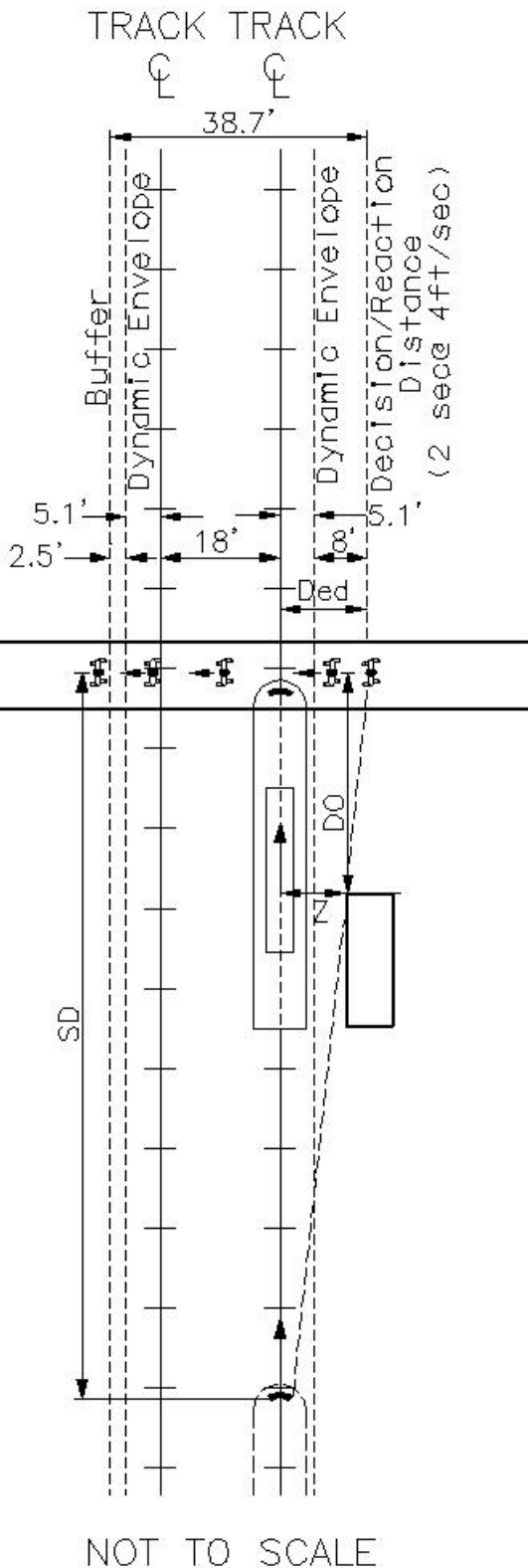
2.5 is the width of the buffer zone beyond the dynamic envelope.

TABLE 19.7.1: LRV Traveling Distances		
LRV Speed	LRV Traveled Distance (ft) in 9.67 sec	Distance (ft) of low fence from pedestrian sight line
15	213	50
25	355	84
35	497	118
45	639	151
55	781	185

Lowered Fence

The fence height will not obstruct a pedestrian's view when 151' or more from the pedestrian based on a distance of 639' covered in 9.67 seconds.

FIGURE 19.7.1.2.2



Use the following formula and table to determine sight distance restrictions:

Pedestrian sight triangle formula: $SD=DO/(1-Z/Ded)$

Where:

SD = Sight distance along track

DO = perpendicular distance from pedestrian to the point on object blocking sight distance

Z = Perpendicular Distance from the point on object blocking sight distance to the centerline of tracks

Ded = Dynamic envelope + Decision/Reaction Distance

TABLE 19.7.2: LRV Stopping Distance

LRV Speed	Normal Braking Stopping distance (ft)	Emergency Braking Stopping Distance (ft)
	Limited Sight Distance	Severe Sight Distance
15	113	85
25	247	182
35	430	345
45	734	577
55	1167	846

- Assume 2.5 seconds for reaction time
- Normal service brake rate from 55 mph to 40mph (2.4mph/s)
- Normal service brake rate from 40 mph to 3 mph (3 mph/s)
- Normal service brake rate from 3 mph to 0 mph (1.5 mph/s)
- Normal emergency brake rate from 55 mph to 30 mph (4 mph/s)
- Normal emergency brake rate from 30 mph to 0 mph (4.5mph/s)

Use Normal braking stopping distance to determine if limited sight restrictions exist. (Emergency Braking Distance < Sight distance < Normal Braking Distance)

Use Emergency braking stopping distance to determine if severe sight restrictions exist. (Sight distance < Emergency Braking Distance)

TABLE 19.7.3 APPLICATION OF PEDESTRIAN SAFETY TREATMENTS

CROSSING WARRANTS	LOWER THAN 35 MPH IN MIXED USE SETTING (See figure 19.7.1.1)	LOWER THAN 35 MPH AT STATION LOCATIONS (See figure 19.7.1.2)	HIGHER THAN 35 MPH AT STATION LOCATIONS (See figure 19.7.1.3)	CROSS STREETS HIGHER THAN 35 MPH (See figure 19.7.1.4)
Does not meet any of the warrants listed below; ordinary	Tactile Warning	Basic Treatment	Basic Treatment; Channeling	Basic Treatment; AT
High Pedestrian Activity	Tactile Warning	Basic Treatment; Channeling	Basic Treatment; Channeling	Basic Treatment; Channeling; AT
Limited Sight Distance Restriction	Tactile Warning	Basic Treatment; Channeling; Barriers	Basic Treatment; Channeling; Barriers	Basic Treatment; Channeling; AT; Swing Gates
Nearside Station	Tactile Warning	Basic Treatment; Channeling; Barriers	Basic Treatment; Channeling; AT	Basic Treatment; Channeling; AT; Automatic Gates
School Zone	Tactile Warning; Channeling; Barriers	Basic Treatment; Channeling; Automatic Gates	Basic Treatment; Channeling; AT; Automatic Gates	Basic Treatment; Channeling; AT; Automatic Gates
Severe Sight Distance Restriction	Tactile Warning; Channeling; Barriers	Basic Treatment; Channeling; Automatic Gates	Basic Treatment; Channeling; AT; Automatic Gates	Basic Treatment; Channeling; AT; Automatic Gates

Basic Treatment: Look Both Ways Signage, Tactile Warning Strip, Stop Here Markings
 Active Treatment (AT): vehicle flashing lights and audible warning will be used for pedestrians in most cases

This chart is intended as a guideline. Each crossing location is unique and will be evaluated to determine which safety treatments are appropriate.

How Does UDOT factor into these guidelines?

Figure 19.7.1.1 MIXED USE SETTING

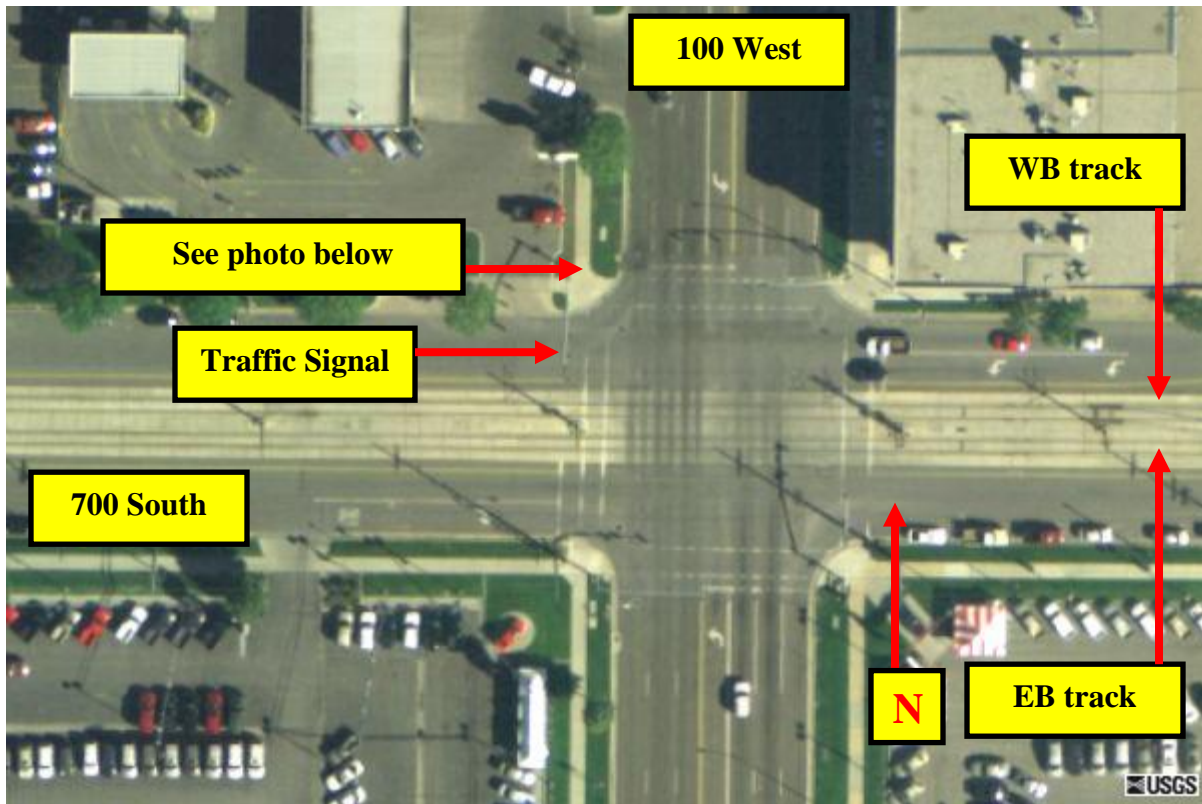


Figure 19.7.1.2 STATION LOCATION

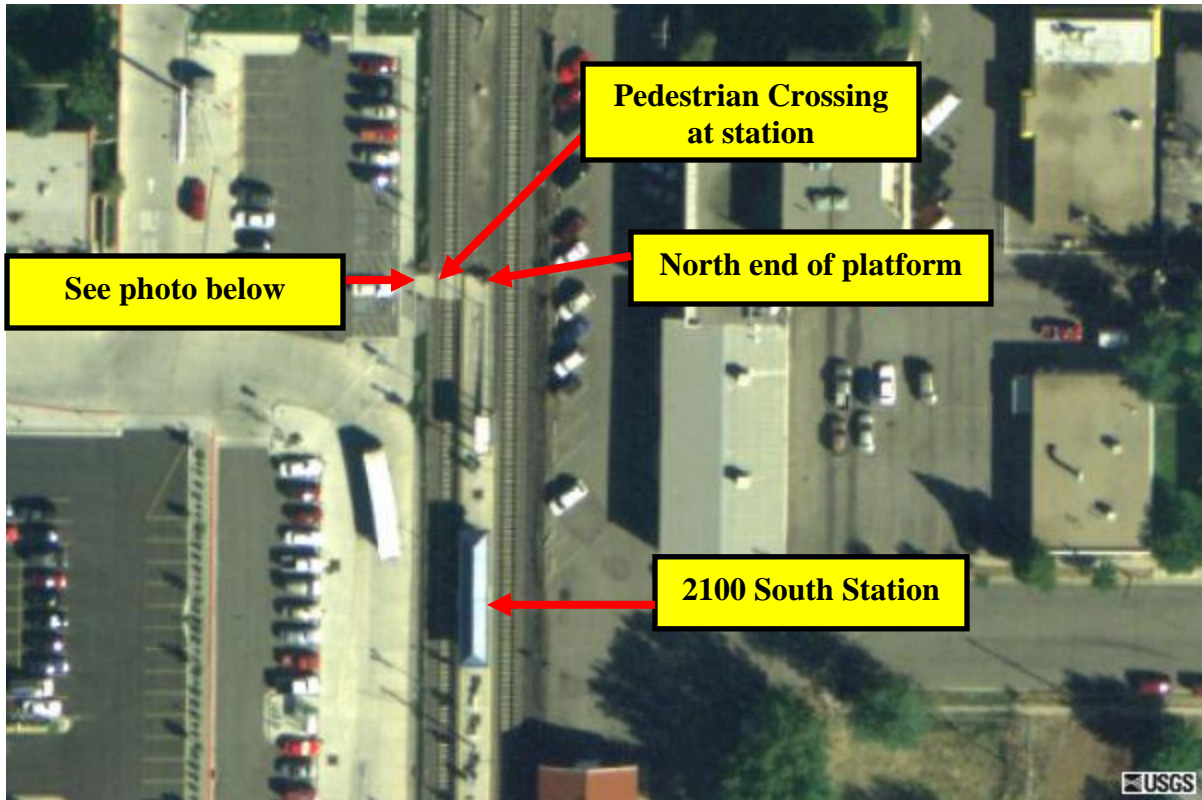
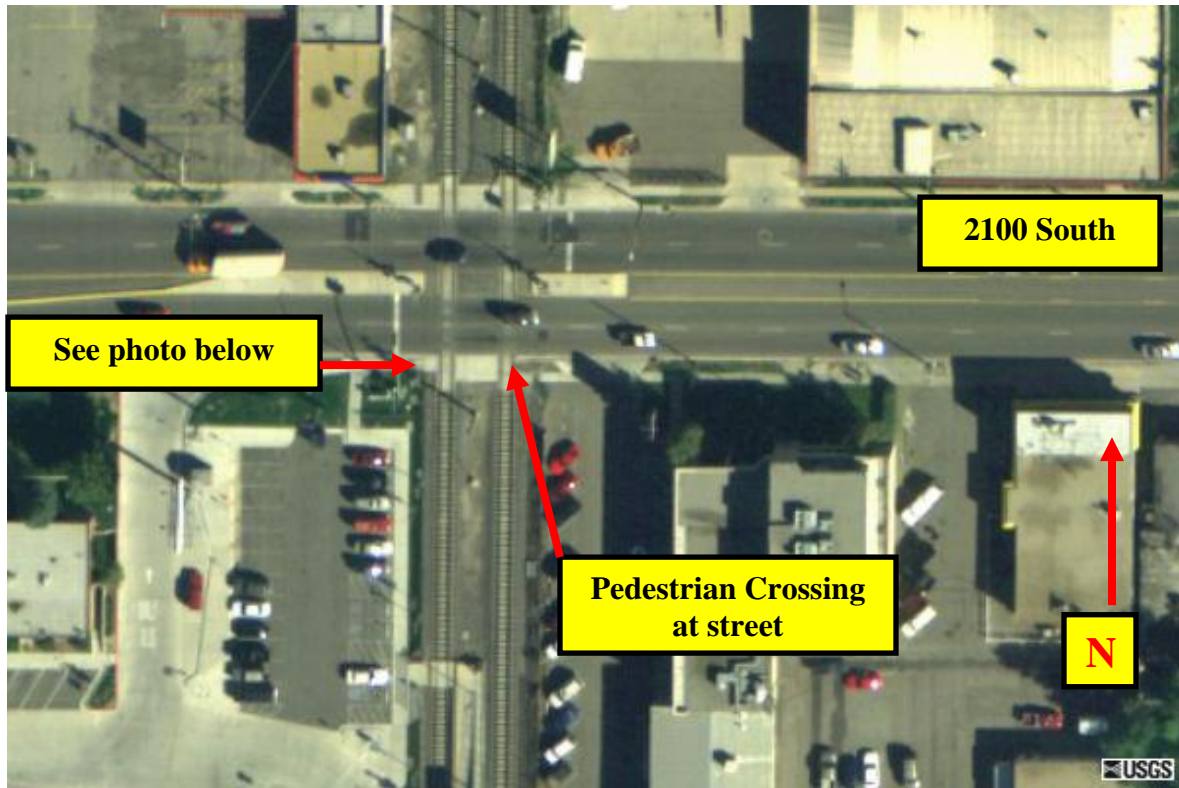
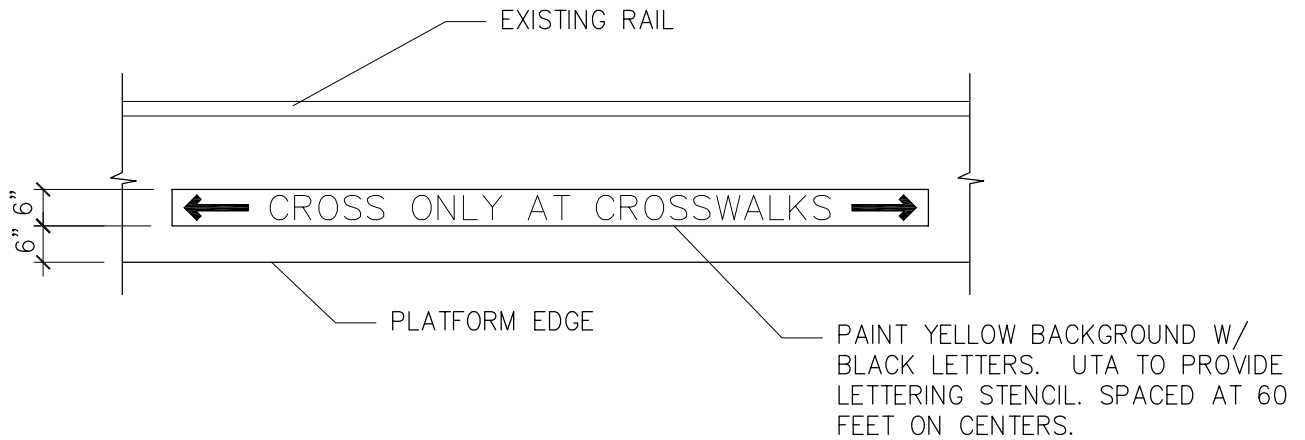


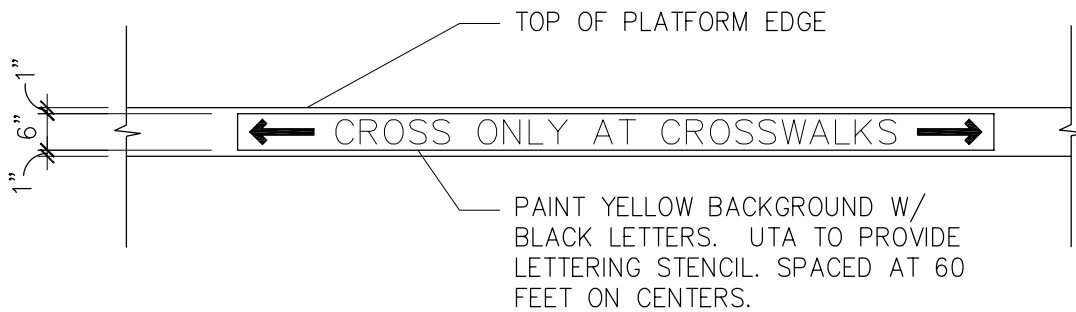
Figure 19.7.1.3 CROSS STREETS SEMI-EXCLUSIVE USE





PAINTED LETTERING ON TRACK WAY AT PLATFORMS

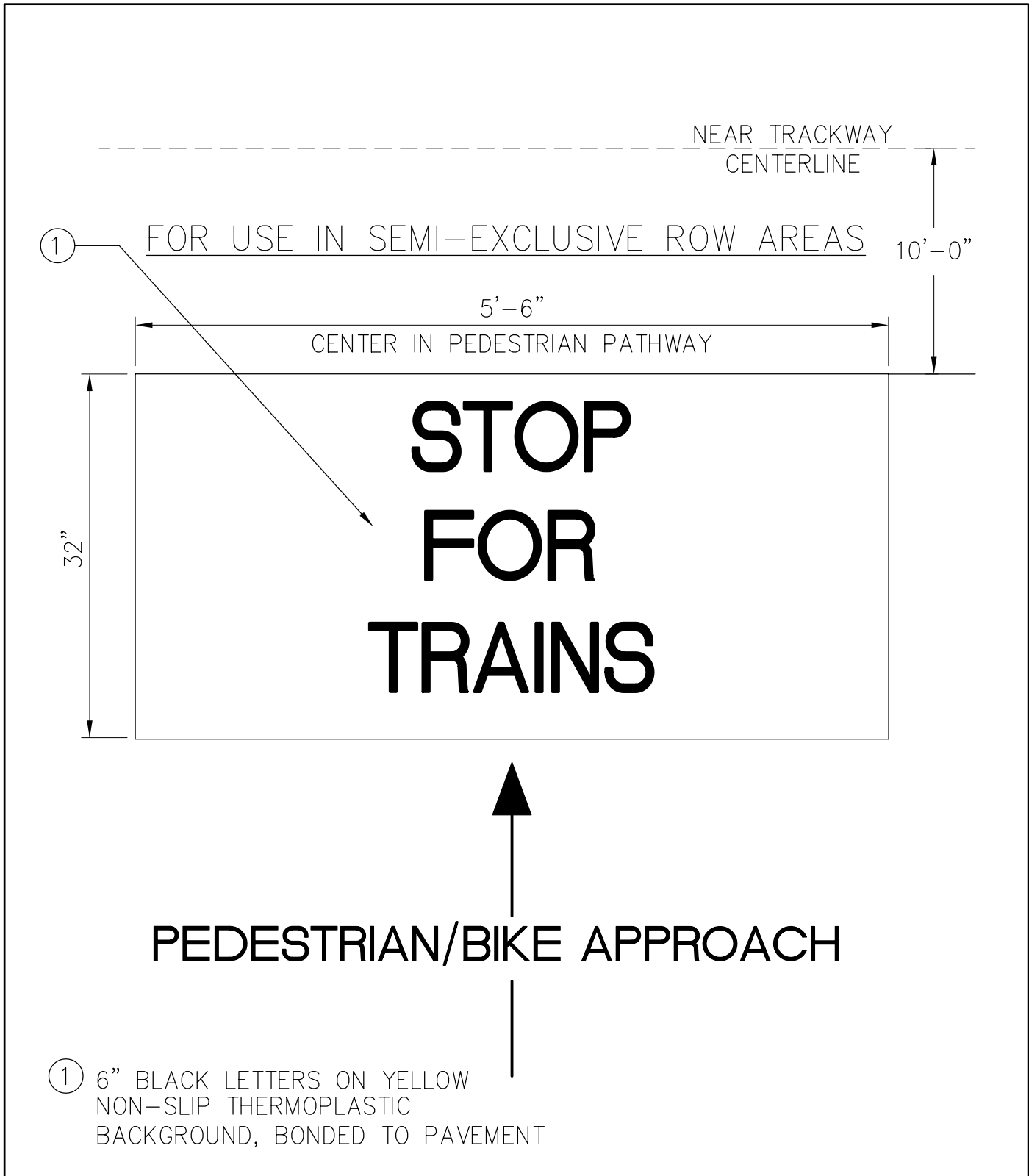
PLAN



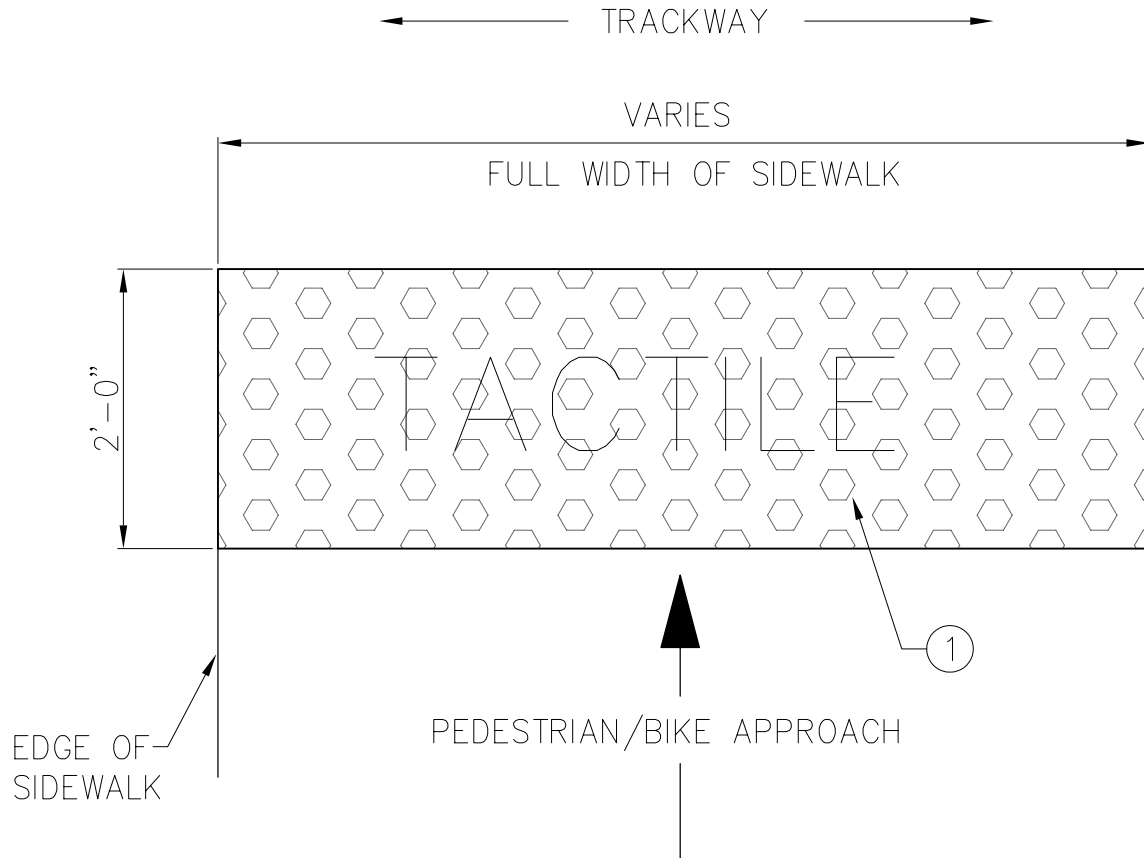
PAINTED LETTERING ON FACE OF PLATFORM

ELEVATION

			PAVEMENT MESSAGE "CROSS ONLY AT CROSSWALKS" WARNING	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-1		CONTRACT NO:	STD DWG: 1



			PAVEMENT MESSAGE	
			"STOP FOR TRAINS" WARNING	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-2		CONTRACT NO:	STD DWG: 2

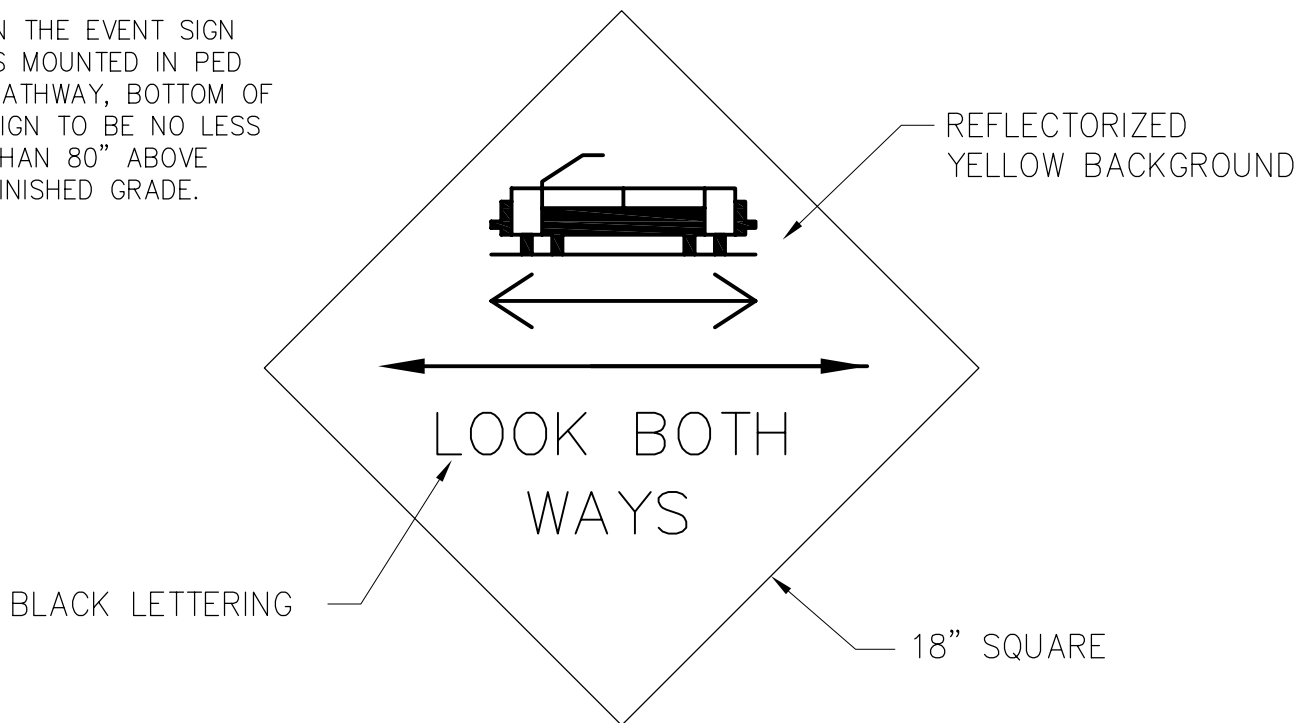


- ① TACTILE WARNING WILL BE YELLOW IN COLOR
- ② COORDINATE WITH JURISDICTION FOR APPLICATION IN JURISDICTION RIGHT-OF-WAY.

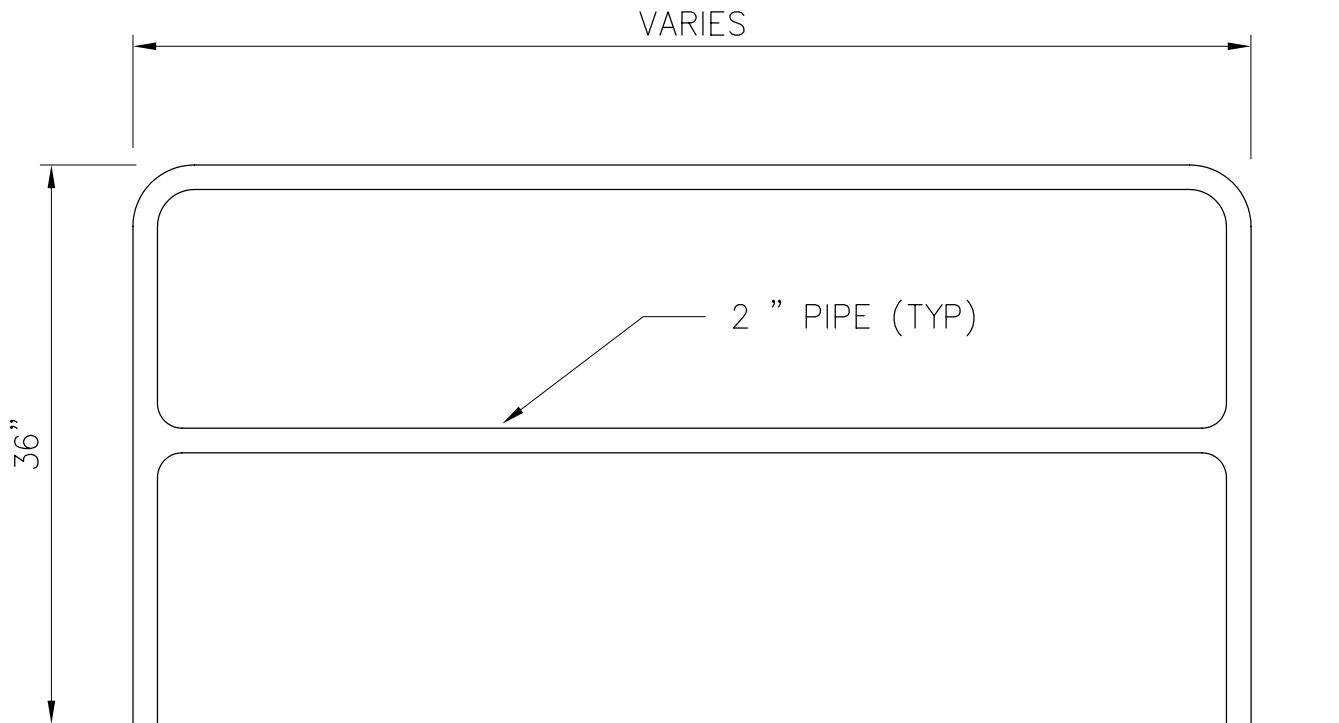
			STANDARD DRAWING PEDESTRIAN TACTILE WARNING	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-3		CONTRACT NO:	STD DWG: 3

NOTES:

1. LOCATION SHALL BE 32" FROM NEAREST EDGE OF PEDESTRIAN PATHWAY TO NEAREST EDGE OF SIGN.
2. IF NECESSARY SIGNS SHALL BE DOUBLE SIDED, OR MOUNTED BACK-TO-BACK.
3. IN THE EVENT SIGN IS MOUNTED IN PED PATHWAY, BOTTOM OF SIGN TO BE NO LESS THAN 80" ABOVE FINISHED GRADE.



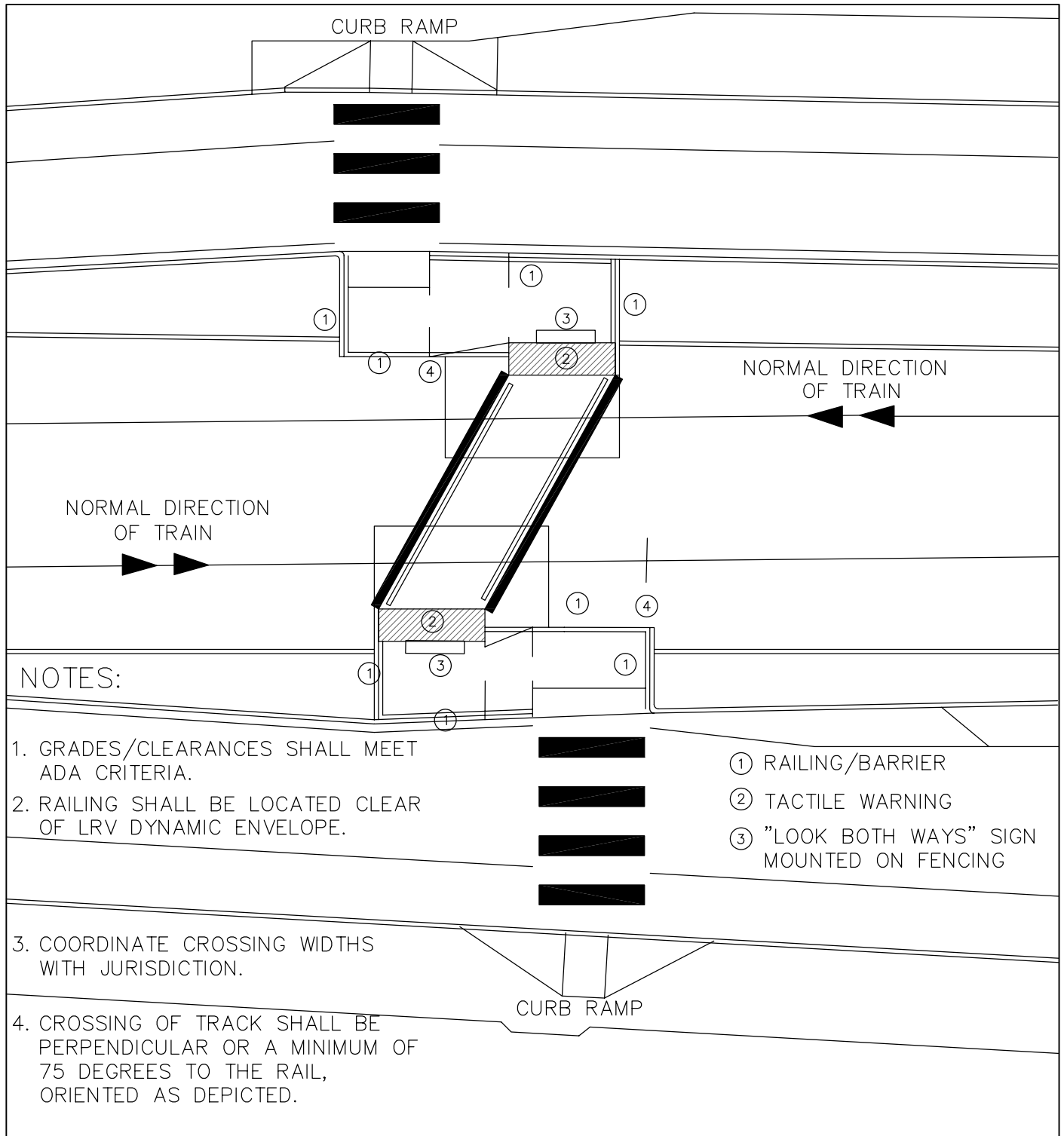
			STANDARD DRAWING "LOOK BOTH WAYS" SIGN	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-4		CONTRACT NO:	STD DWG: 4



NOTES:

1. DESIGN LOCATION AND LENGTH OF RAILING SO THAT CHANNELING REDUCES UNAUTHORIZED CROSSING OF TRACKWAY.
2. RAILING SHALL NOT INTRUDE INTO VEHICULAR DYNAMIC ENVELOPE
3. COORDINATE SET BACK FROM ROADWAY WITH JURISDICTION.
4. OTHER EFFECTIVE CHANNELING METHODS, SUCH AS THROUGH THE USE OF LANDSCAPING OR FENCING MAY ALSO BE APPROPRIATE IN CERTAIN SITUATIONS.

			STANDARD DRAWING PEDESTRIAN CHANNELING TYPICAL RAILING	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-5		CONTRACT NO:	STD DWG: 5

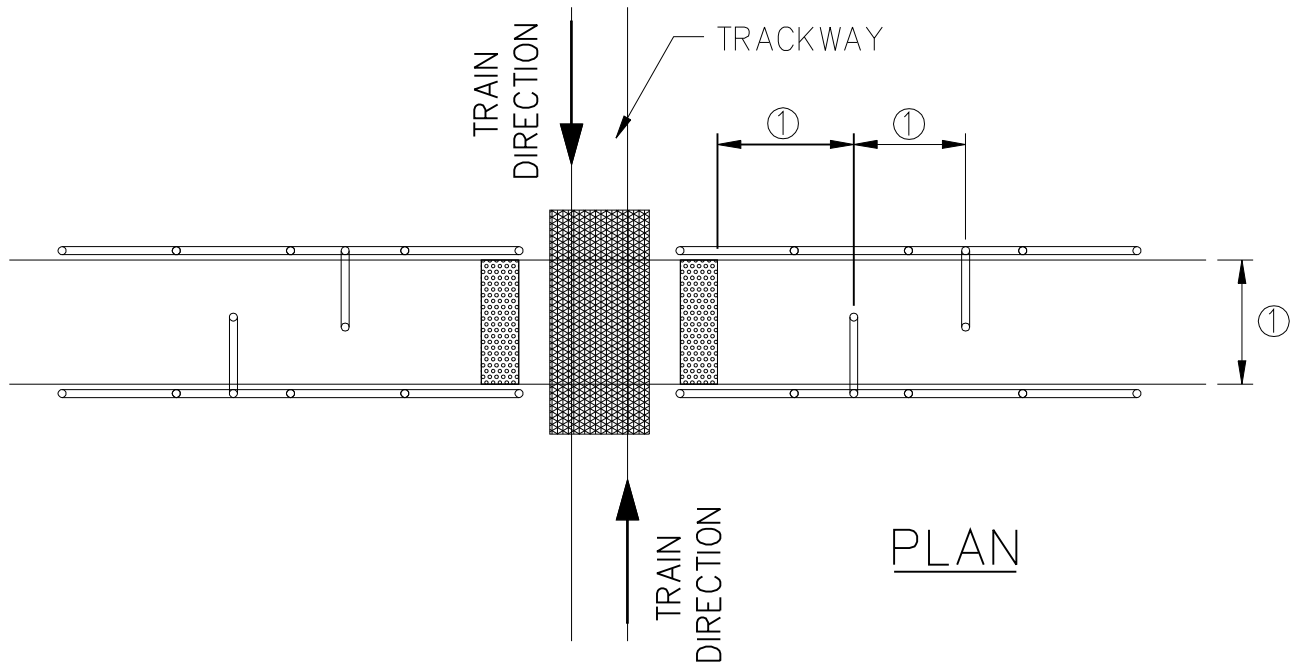


NOTES:

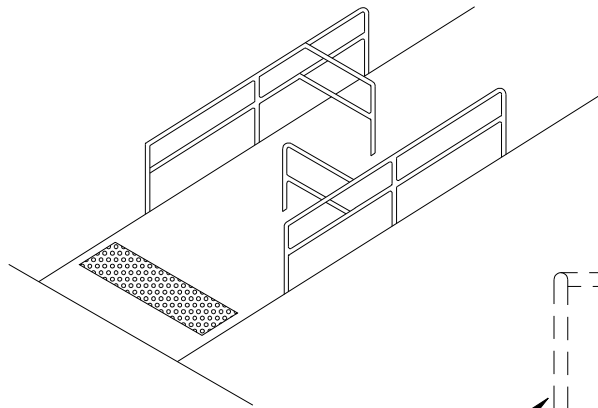
- 1. GRADES/CLEARANCES SHALL MEET ADA CRITERIA.
- 2. RAILING SHALL BE LOCATED CLEAR OF LRV DYNAMIC ENVELOPE.
- 3. COORDINATE CROSSING WIDTHS WITH JURISDICTION.
- 4. CROSSING OF TRACK SHALL BE PERPENDICULAR OR A MINIMUM OF 75 DEGREES TO THE RAIL, ORIENTED AS DEPICTED.

- ① RAILING/BARRIER
- ② TACTILE WARNING
- ③ "LOOK BOTH WAYS" SIGN MOUNTED ON FENCING

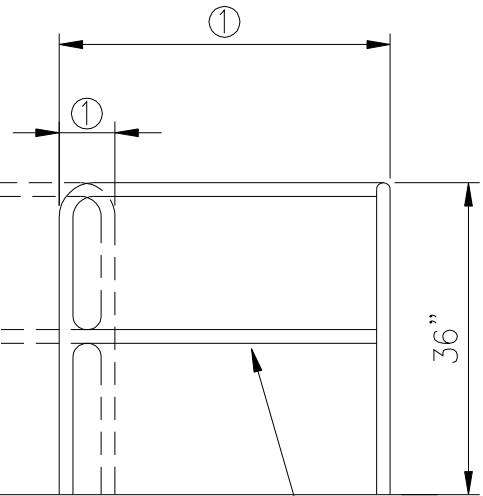
				<p>STANDARD DRAWING TYPICAL PED Z-CROSSING</p>	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:	
SCALE:	FILE NAME: I\Gen. Proj. & Files\Standard Dwgs\Ped. Crossings\STD-6		CONTRACT NO:	STD DWG: 6	



PLAN



REAR GATE



36"

FRONT GATE

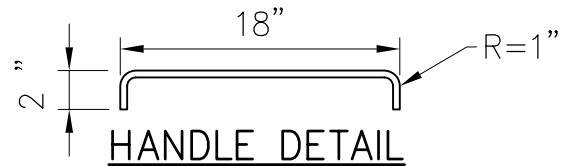
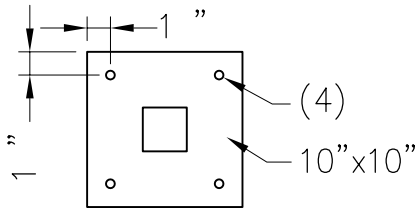
SIDE VIEW

NOTE:

- ① LAYOUT AND SPACE RAILING TO ACCOMODATE ACCESS BY HANDICAPPED PERSONS.
- ② BARRIER MUST EXTEND FAR ENOUGH ACROSS WALKWAY TO HAVE PEDESTRIANS FACE ONCOMING LIGHT RAIL VEHICLES.

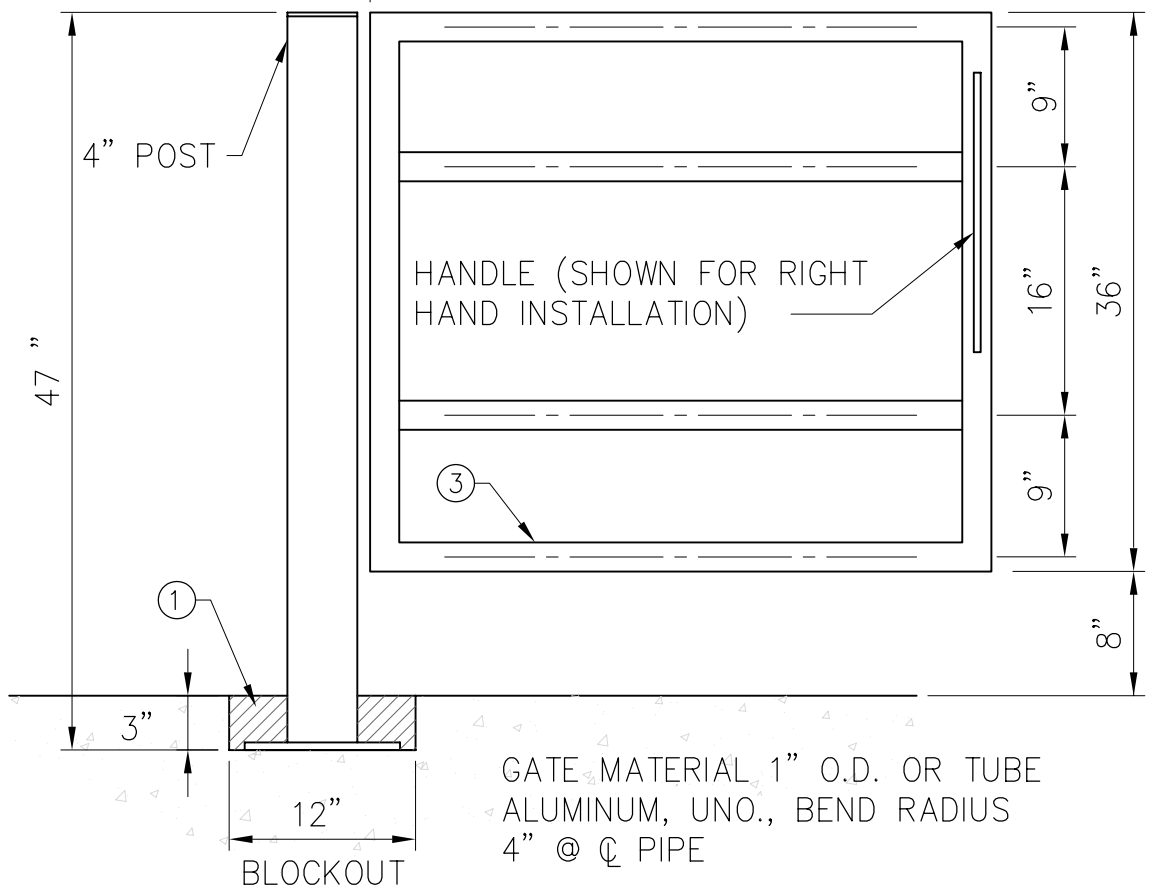
				STANDARD DRAWING PEDESTRIAN BARRIER (BEDSTEAD)	
DRAWN	DESIGN	CHECKED CHECKED	APPROVED:	DATE:	
SCALE:	FILE NAME: \Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-7		CONTRACT NO:	STD DWG: 7	

- ① RECESS BASEPLATE. ANCHOR TO CONCRETE SLAB. FINISH TO MATCH ADJACENT SURFACES.
- ② GROUND ALL METAL TO EXISTING GROUND GRID OR APPROVED ALTERNATIVE.
- ③ FINISH TO BE ALUMINUM OR POWDER-COAT PAINT TO CONFORM WITH APPROVED COLOR SCHEME.
- ④ GATES SHALL SWING OPEN AWAY FROM TRACKWAY AND RETURN TO ITS CLOSED POSITION THROUGH GRAVITY OPERATION.
- ⑤ PLACE POST BEHIND SIDEWALK ON SIDEWALK THAT IS AT LEAST 60" WIDE TO MEET ADA REQUIREMENTS.
- ⑥ SEE STANDARD DRAWING 8.1 FOR CAMLIFT HINGE DETAIL



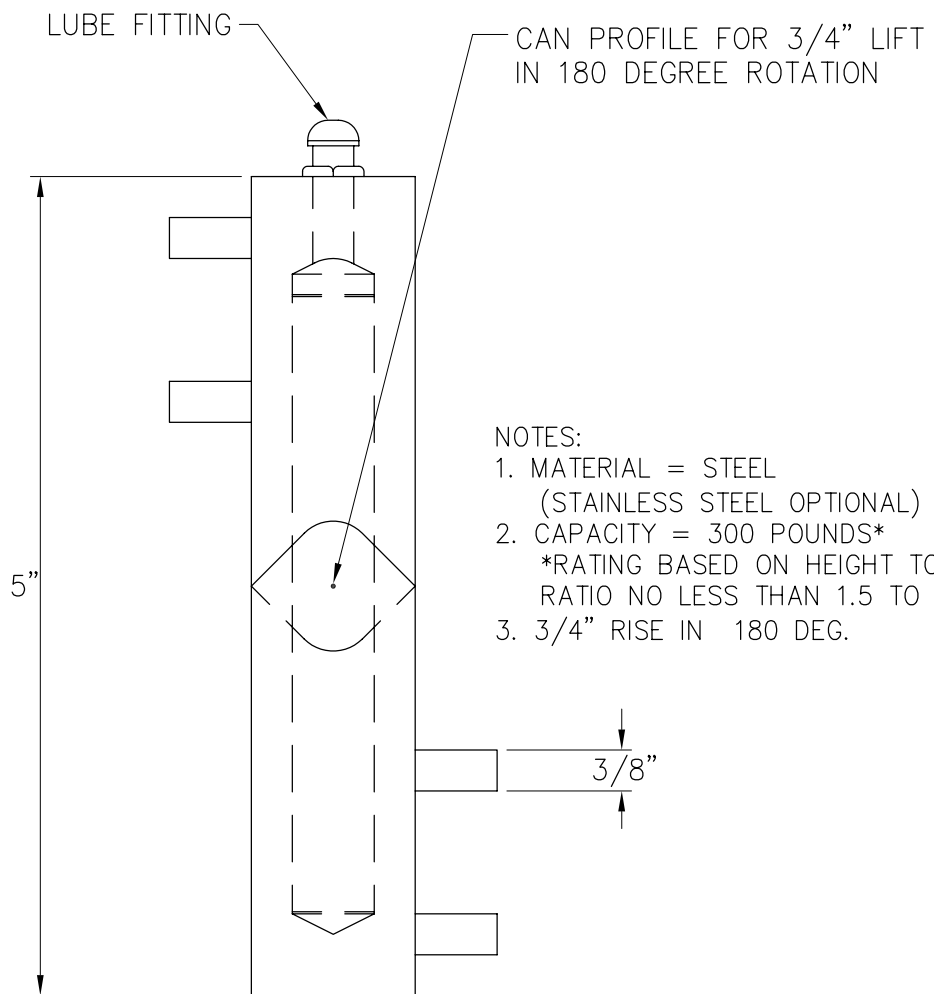
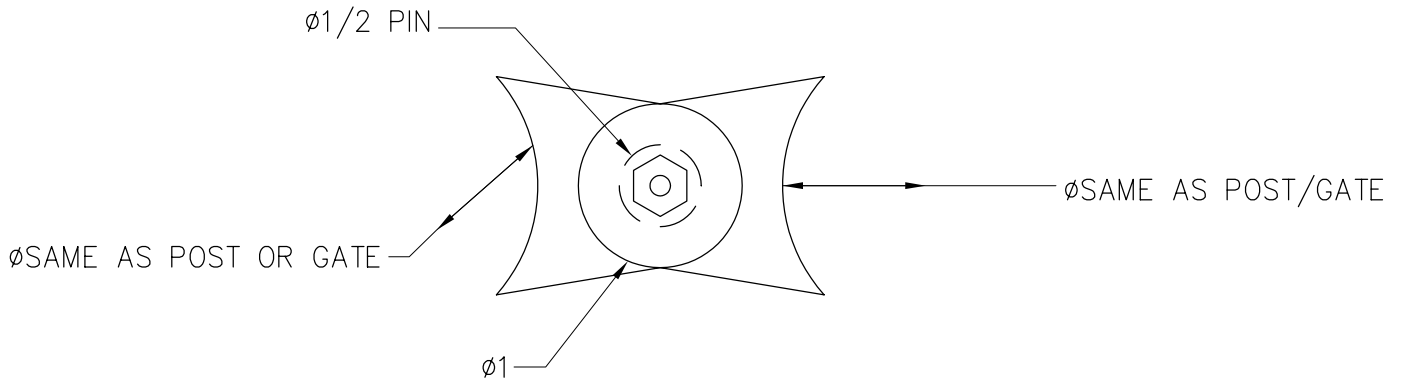
BASE PLATE

40"



GATE MATERIAL 1" O.D. OR TUBE ALUMINUM, UNO., BEND RADIUS 4" @ \perp PIPE

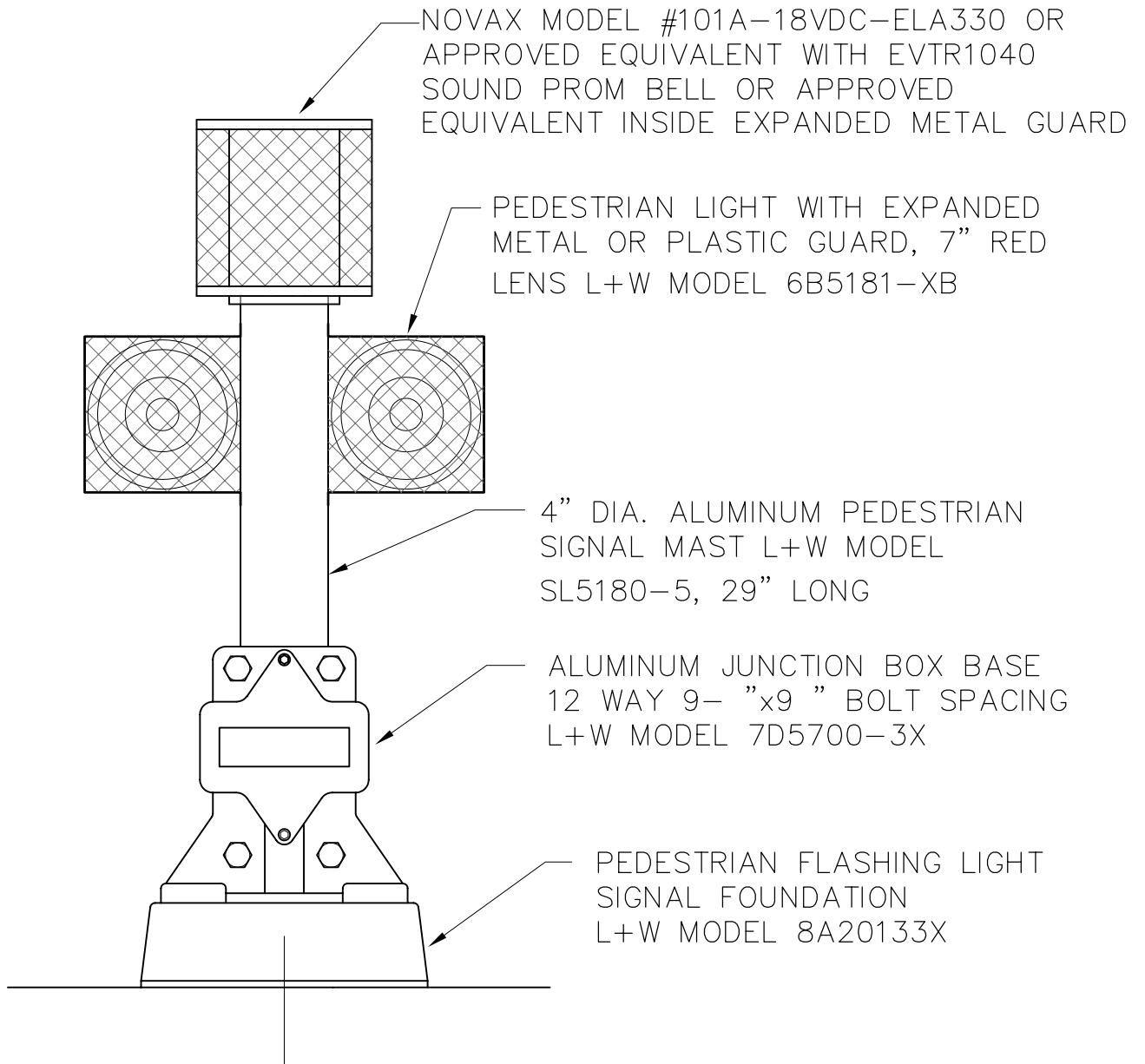
				STANDARD DRAWING	
				SWING GATE	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:	
SCALE:	FILE NAME: I\Gen. Proj. & Files\Standard Dwgs\Ped. Crossings\STD-8		CONTRACT NO:	STD DWG: 8	



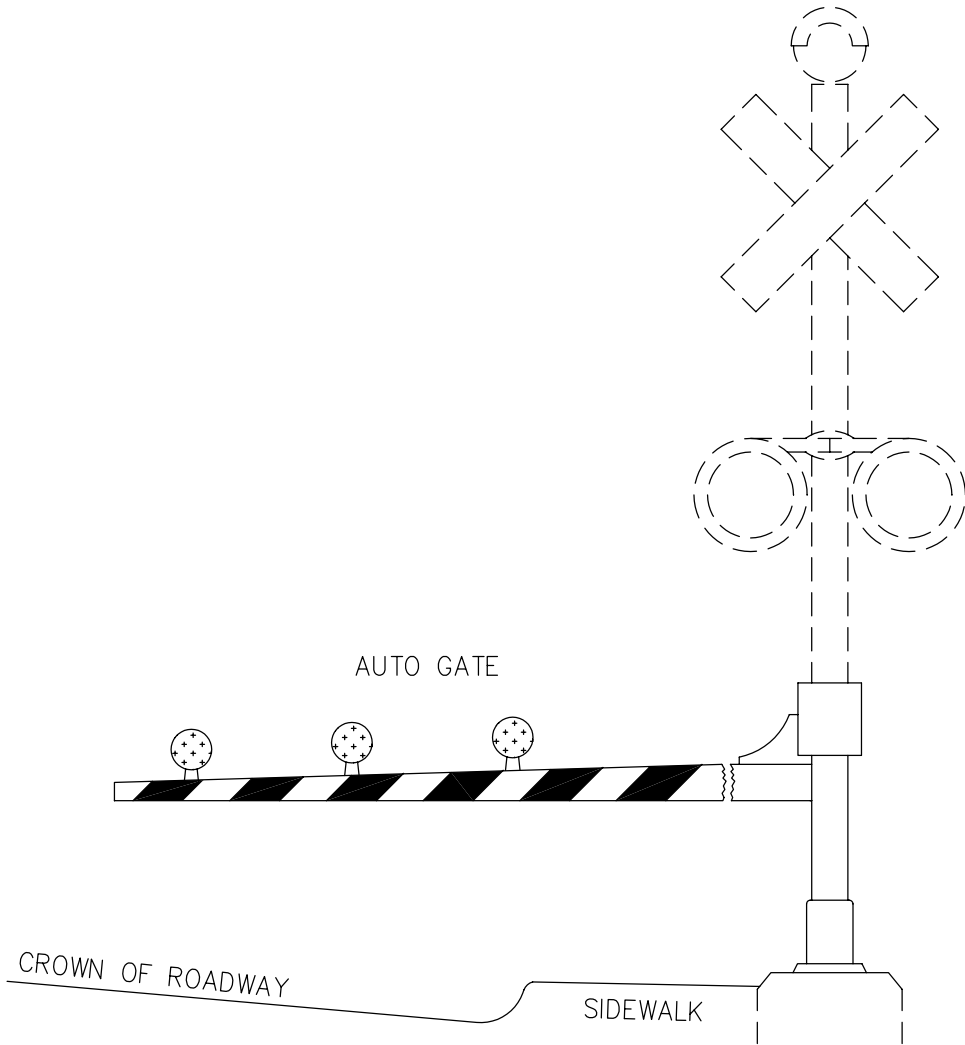
NOTES:

1. MATERIAL = STEEL
(STAINLESS STEEL OPTIONAL)
2. CAPACITY = 300 POUNDS*
*RATING BASED ON HEIGHT TO WIDTH
RATIO NO LESS THAN 1.5 TO 1
3. 3/4" RISE IN 180 DEG.

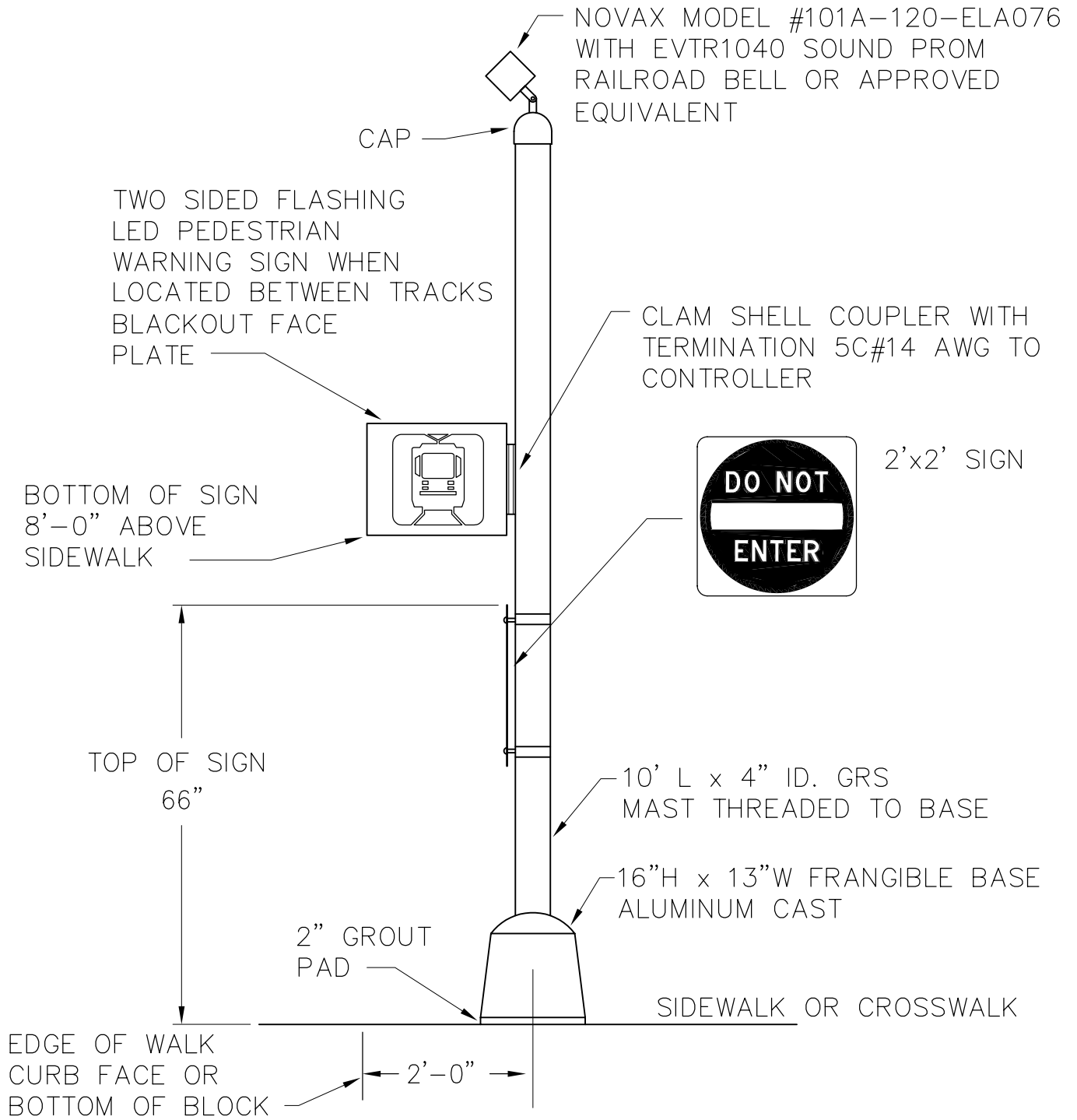
			<p>STANDARD DRAWING CAMLIFT HINGE DETAIL</p>	
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SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-8.1		CONTRACT NO:	STD DWG: 8.1



			STANDARD DRAWING PEDESTRIAN FLASHING LIGHTS AND AUDIBLE WARNING DEVICE	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-9		CONTRACT NO:	STD DWG: 9

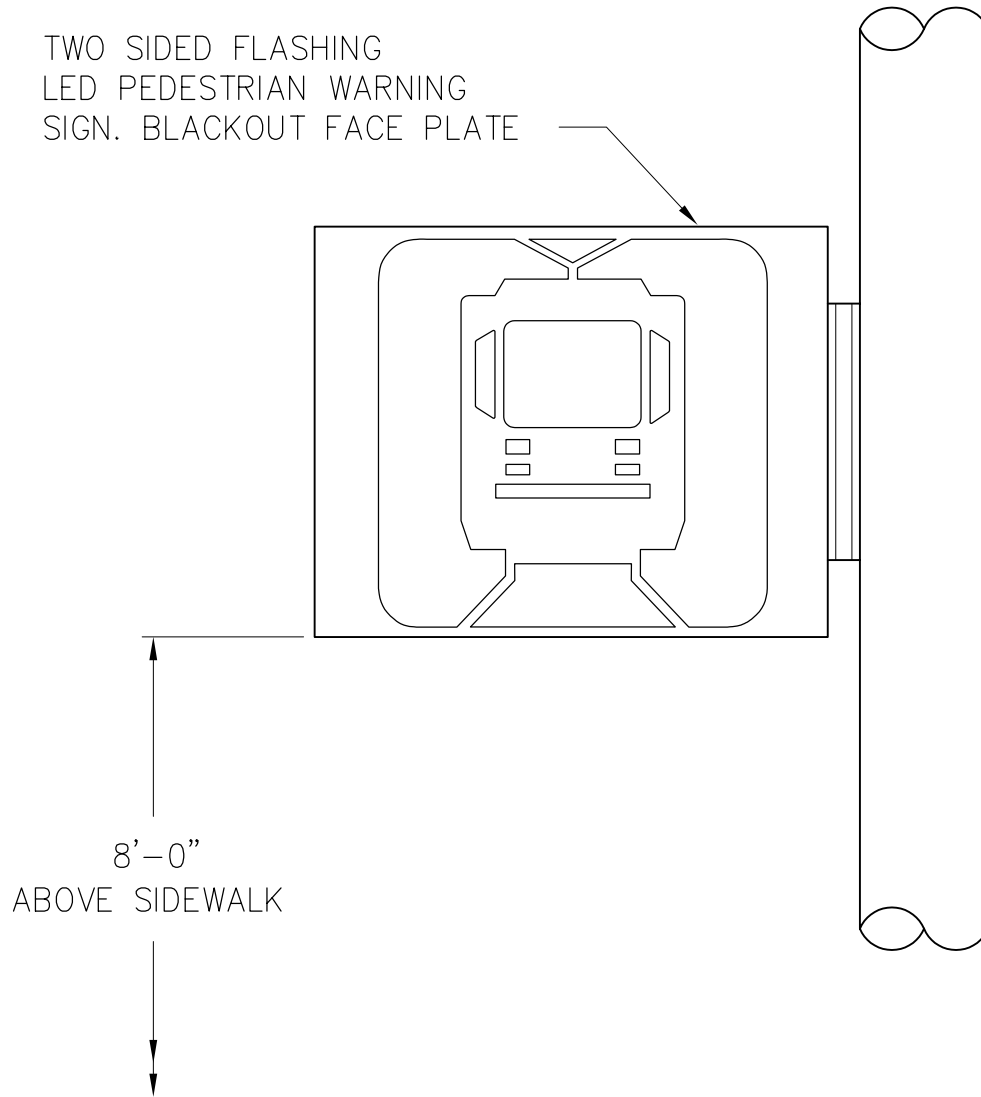


			STANDARD DRAWING VEHICLE/PEDESTRIAN GATE	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-10		CONTRACT NO:	STD DWG: 10

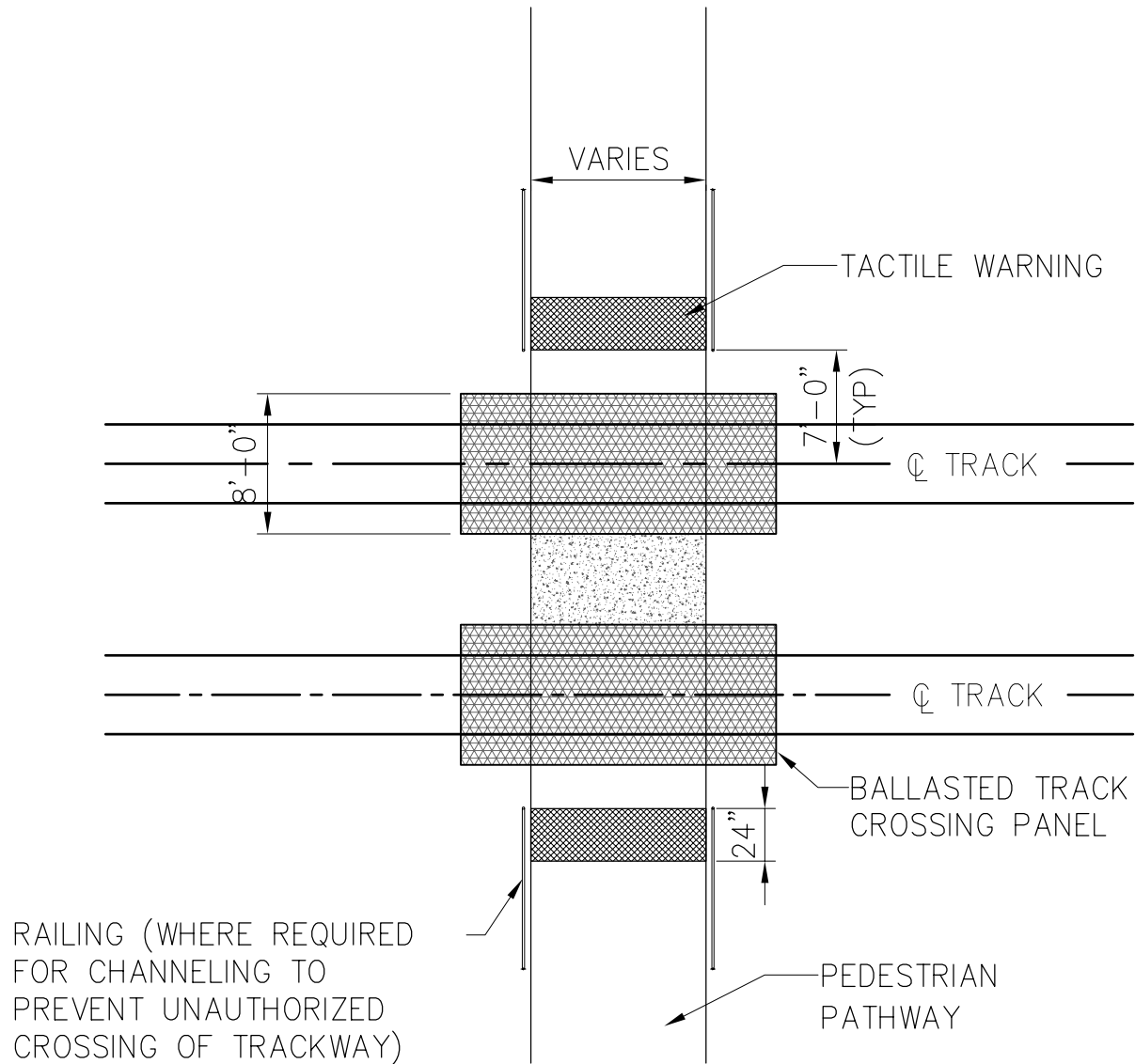


			STANDARD DRAWING LRV-ACTIVATED LRT VISUAL/AUDIO WARNING	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-11		CONTRACT NO:	STD DWG: 11

TWO SIDED FLASHING
LED PEDESTRIAN WARNING
SIGN. BLACKOUT FACE PLATE



			STANDARD DRAWING TWO SIDED FLASHING LED PED WARNING SIGN	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-12		CONTRACT NO:	STD DWG: 12



			STANDARD DRAWING TYPICAL AT-GRADE INSTALLATION	
DRAWN	DESIGN	CHECKED	APPROVED:	DATE:
SCALE:	FILE NAME: I\Gen. Proj. & Files\ Standard Dwgs\Ped. Crossings\ STD-13		CONTRACT NO:	STD DWG: 13

END OF CHAPTER