CITY OF EDMONTON HIGH FLOOR LRT DESIGN GUIDELINES

COE-IM-GUIDE-0017 | v02
Date of Issuance: 2022-03-30

Edmonton ETS

INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

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Ver	Date	Revision Summary
01	2019-12-01	Major re-write and re-organization of the design guidelines.
02	2022-03-30	The complete design guideline was reviewed and updated to include new/ revised content, remove superseded content, and re-arrange some content, all required for professional authentication of various chapters.
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CHAPTER 1

General

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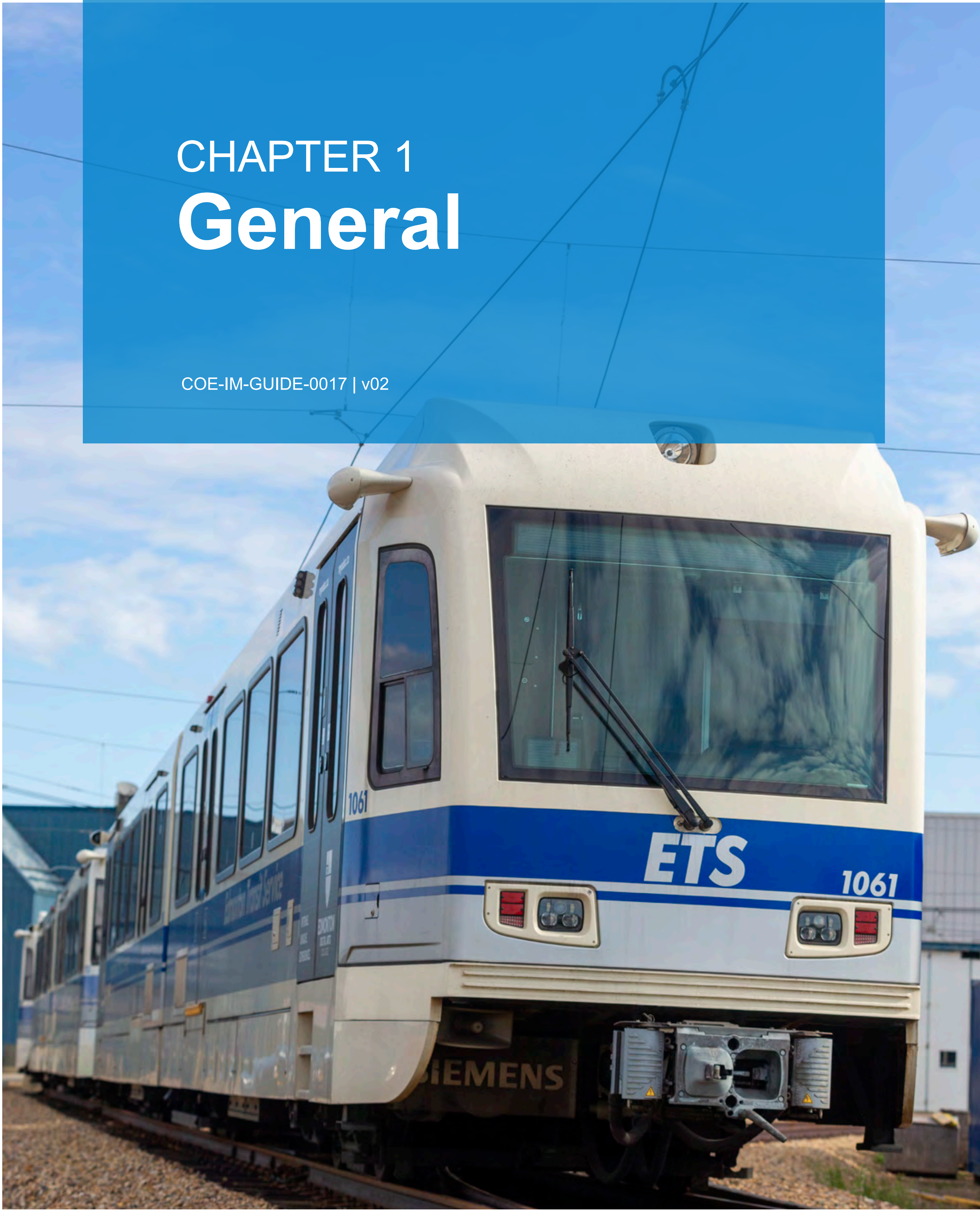

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See complete Intent of Use Statement following the cover page.

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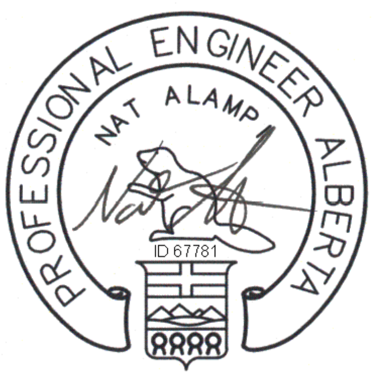

29-Mar-2022

Permit to Practice

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The Association of Professional Engineers and Geoscientists of Alberta

1 GENERAL

1.1 INTRODUCTION

1.1.1 Purpose

This document presents guidelines, design criteria, and information for City of Edmonton staff, Designers, and Contractors, to establish a uniform basis for the design of Light Rail Transit (LRT) projects for the City of Edmonton's high floor LRT System, consisting of the Capital Line and the Metro Line. These guidelines apply to expansion, rehabilitation, and renewal projects.

This chapter provides overarching information that impacts multiple aspects of a Design, defines key roles and responsibilities when designing a project, and provides references to other documents and processes that must be considered when developing Designs.

1.1.2 Acronyms

A list of acronyms that are used throughout these guidelines is provided in Chapter 18, Acronyms. Note that acronyms reflect both singular and plural use.

1.1.3 Definitions

A list of defined terms that are used throughout these guidelines is provided in Chapter 19, Definitions. Defined terms are capitalized throughout these guidelines.

1.1.4 Applicable Codes, Standards, and Regulations

Other guidelines, policies, and standards documents are referenced in these guidelines and must be considered in the Design and, where applicable, into the preparation of Contract Documents. Most documents owned by the City can be found on the City of Edmonton's website (www.edmonton.ca). Requests for documents that are not available online must be directed to the Engineer.

The lists of applicable codes and standards in each chapter of these guidelines are not exhaustive and the Designer must be aware of and follow all current codes and standards that apply to their Design.

All Contract Documents should specify the date of the current version of each of the other documents that the Designer and Contractor must comply with in the implementation of the Design.

If there is a discrepancy between these guidelines and the various codes, standards, regulations and other guidelines referenced herein, then the Designer must apply the requirement which provides the greatest utility and safety for the end users. Alternatively, the Designer may seek direction from the Engineer regarding which requirement applies and must be incorporated in the Design. Should a variance be required due to discrepancies between applicable codes, standards, regulations, and guidelines, then a variance must be applied for as described in Section 1.3.1.

Design and construction of LRT facilities and systems must comply with all current municipal, provincial, and federal codes and standards where applicable. Where differences between the various codes and standards occur, the Designer must assess the merits of differing requirements and provide a recommendation to the Engineer, who will provide direction.

If warranted, the Designer must consult with the Authority Having Jurisdiction (AHJ), being a safety codes officer in the buildings discipline exercising authority pursuant to designation of power and terms of employment in accordance with Section 28 of the Safety Codes Act. For all non-safety matters, the AHJ will be the Engineer. The AHJ must be further defined in the Contract Documents.

The Systems Assurance Guideline provides details on the system assurance process and requirements, including safety certification, and identifies the Operator as the AHJ for final acceptance of a commissioned LRT project.

Should the Designer determine that any of these requirements are inappropriate or conflicting for a given project, then, subject to a request made by the Designer, the Engineer may determine which or any of the requirements must be incorporated into the Design. Such requests must be made in accordance with the Design Guideline Variance Request procedure in Section 1.3.1.

1.1.4.1 Acts, Codes and Regulations

- National Building Code - Alberta Edition (Alberta Municipal Affairs, Current Edition) [1]
- Canadian National Building Code of Canada (Government of Canada, Current Edition) [2]
- CSA S6 – Canadian Highway Bridge Design Code [3]
- Safety Codes Act (Province of Alberta, Current Edition) [4]

1.1.4.2 Bylaws and Policies

- Accessibility for People with Disabilities Policy C602
- Edmonton Design Committee, Bylaw 14054 [5]
- Infrastructure Asset Management Policy C598 [6]
- Light Efficient Community Policy C576 [7]
- Public Engagement Policy C593 [8]
- Percent for Art Policy C458 [9]
- Sustainable Building Policy C532 - Leadership in Energy and Environmental Design (LEED Silver) [10]
- Zoning Bylaw 12800 [11]
- Climate Resilience Policy C627

1.1.4.3 Reference Standards

- Edmonton Design and Construction Standards [12]
- Edmonton Roadway and Walkway Lighting Design Standards [13]
- Barrier-Free Design Guide, Safety Codes Council of Alberta [14]
- Edmonton Complete Streets Design & Construction Standards [15]
- Transportation Association of Canada’s Geometric Design Guide for Canadian Roads [16]
- National Fire Protection Association, NFPA 130 [17]

1.1.4.4 Other City of Edmonton Guidelines and Reference Documents

- Access Design Guide (City of Edmonton) [18]
- Commissioning Consultant Manual: Volume 1 – Whole Building Commissioning Process and Guidelines [19]
- Commissioning Consultant Manual: Volume 2 – Building Envelope Commissioning Process and Guidelines [20]
- Facility Design & Construction Consultant Manual: Volume 1 – Design Process and Guidelines [21]
- Facility Design & Construction Consultant Manual: Volume 2 – Technical Guidelines [22]
- High Floor Light Rail Vehicle (LRV) Specifications

- Long-Term High Floor LRT Signaling & Train Control Strategy
- Long-Term High Floor LRV Operations & Maintenance Facility Strategy
- LRT Testing & Commissioning Guidelines
- LRT Rule Book
- Systems Assurance Guideline
- LRT Standard Operating Procedures Manual
- Standard Record Documents Guideline for High Floor LRT Projects
- Transit Oriented Development Guidelines [23]
- Urban Design Framework [24]
- Winter Design Guidelines [25]

1.1.5 Mandatory vs. Non-Mandatory

These guidelines include both mandatory requirements and non-mandatory recommendations. Application of these guidelines is based on use of the following terminology:

- Must – denotes a mandatory City of Edmonton requirement
- Should – denotes a recommended, but non-mandatory City of Edmonton requirement
- May – denotes an optional City of Edmonton requirement

1.2 SYSTEM DESCRIPTION

The LRT System consists of a mix of At-Grade centre-running and side-running double track, with sections that are Grade Separated. Station types include center-loading and side-loading Platforms, and staggered Platforms may be considered with future extensions. Designs should be developed with the intent of minimizing Right-of-Way (ROW) acquisition, environmental impacts, and neighbourhood impacts. The need for a Grade Separated Trackway and Grade Separated Stations must be evaluated on a case-by-case basis.

The LRT System runs through a range of corridor types, from higher speed commuter corridors to lower speed urban settings. When designing Stations and Ancillary Facilities for each section of the LRT System, the Designer must consider local context and the intended LRT operating mode.

1.2.1 Urban Style Light Rail Transit

The City of Edmonton has adopted an Urban Style LRT design philosophy that shares guiding principles of Sustainable Urban Integration (SUI) for all aspects of the LRT System. The City's Urban LRT Leadership Charter is included in Appendix 1A for reference.

The Designer must refer to Chapter 14, Urban Integration for information on SUI implementation. An Urban Style LRT Design must adhere to the following key principles:

- Infrastructure scale – building smaller scale Stations that are spaced at 800 m to 1000 m intervals to promote walkability and other active transportation modes
- Accessibility – providing better links to a greater number of destinations, with more direct transit, pedestrian, and cyclist connections
- Safety – maximizing openness of space to create a safe environment
- Respecting communities – reducing speeds in congested areas to support safe pedestrian-oriented communities with reduced ROW, fewer barriers, and improved visual appeal
- Public realm design – investing in landscaping, streetscaping, and architectural features to improve visual appeal, including Station differentiators, such as Wayfinding and sense of identity

The ability to apply SUI elements to each segment of the LRT System will be dependent on many variables including local context, LRT operating speed, safety, and security.

1.2.2 Light Rail Transit System Zones

The LRT System consists of the following four zones:

- LRT ROW – Refer to Chapter 3, Clearances and Right-of-Way and Chapter 4, Track Alignment
- Streets – Refer to Chapter 17, Streets
- Stations – Refer to Chapter 10, Stations and Ancillary Facilities
- Urban Interface – Refer to Chapter 14, Urban Integration

The Design of the LRT System must account for not only the LRT infrastructure, but also any adjacencies and the interfaces between the zones.

1.2.3 Operating Frequency

The LRT System provides a bi-directional service which generally operates with the following frequencies in each direction on each of the Capital Line and Metro Line:

- Peak hours: 5-minute headways
- Mid-day and weekends: 10-minute headways
- Evenings: 15-minute headways
- Special events: 5-minute (or less) headways
- Single tracking operations: minimum 15-minute headways must be attainable

The Designer must account for overlapping of the Capital Line and Metro Line services between Health Sciences Station and Churchill Station, resulting in Trains operating more frequently in that section of the LRT System.

1.2.4 Corridors & Operating Modes

LRT System operation is dependent on the type of Transportation Corridor as well as system safety and security. The Transportation Corridor type also influences the ability to apply SUI elements. Exclusive Use Corridors include LRT-only tunnels and elevated guideways however the majority of the LRT System is currently in non-Exclusive Corridors. The characteristics of non-Exclusive Corridor types are:

1.2.4.1 Semi-Exclusive Corridor

- No parallel or adjacent roadways
- Infrequent crossings of higher speed and higher volume roadways
- No direct land-use access to the Transportation Corridor

1.2.4.2 Shared Use Corridor

- Higher speed parallel and adjacent roadways permitted
- Opportunity for more frequent, lower volume crossings
- Access to the Transportation Corridor limited to industrial, commercial, and higher density residential development

1.2.4.3 Urban Corridor

- Lower speed parallel and adjacent roadways permitted
- Frequent controlled crossings permitted
- Direct access to the corridor from all land-uses permitted

Appendix 1B presents requirements and parameters for operating speeds and signaling types within different non-Exclusive Corridors. This table must be used to inform all stages of design and is especially critical through the corridor selection and concept planning phases as described in Section 1.4.1 of these guidelines.

There are no existing or planned Mixed-Use operations on the LRT System, therefore that operating scenario is not contemplated in Appendix 1B.

1.3 DESIGN CONSIDERATIONS

The operational goal of the LRT System is to provide a reliable, safe, and comfortable public transportation system in a cost effective, environmentally sensitive, and socially responsible manner. In addition to the criteria in these guidelines, the Designer must be aware of other requirements that will influence the Design.

1.3.1 Procedures and Applications

The Designer must complete the Design in accordance with these guidelines, which contain information that will provide a uniform basis for developing the Design. It is not intended to restrict Designers in exploring new ideas, concepts, and application of new technologies that meet or exceed existing standards and are sustainable from a maintenance perspective.

These guidelines do not substitute for engineering judgement and sound engineering practice. Exceptions to the guidelines may apply in special cases. Applications for exceptions, deviation, changes, or additions to the guidelines, and any questions regarding the guidelines, must be submitted to the Engineer for review and approval.

If the Designer is seeking a variance from the guidelines, the Designer must submit an official variance request in writing to the Engineer explaining and justifying the requested deviation. A sample variance request form is included as Appendix 1C. The Engineer will evaluate the Designer's request, consult with internal City departments (including the Operator), and notify the Designer of the acceptance or rejection of suggested revisions or exceptions.

1.3.2 Communication, Collaboration, and Approvals

Unless otherwise directed by the Engineer, any communication from the Designer must be addressed to the Engineer. The Engineer will coordinate with the Operator or other entities as necessary. Decisions on acceptance of the Designer's proposals or requests for information will only be made by the Engineer.

As directed by the Engineer, early and proactive stakeholder consultation must occur throughout the design development process to ensure key stakeholder input is appropriately collected and addressed in the Design. Key stakeholders include, but are not limited to:

- All Owner and Operator departments, branches and sections (as identified by the Engineer when scoping the project).
- The Advisory Board for Persons with Disabilities
- Edmonton Transit System Advisory Board
- The Edmonton Design Committee
- The Edmonton Arts Council
- EPCOR

Not all key stakeholders listed above may need to be consulted on every project. The Engineer will assess each project on a case-by-case basis to determine which key stakeholders must be consulted during the Design process.

Depending upon the project, coordination or approval may be required from other government agencies (provincial or federal), regulatory bodies, heavy freight rail agencies, or medical institutions.

1.3.3 Renewal and Rehabilitation Projects

Renewal and rehabilitation projects are often constrained by available funding and may require grandfathering of existing infrastructure that was constructed to different standards. These guidelines will therefore apply to varying degrees on renewal and rehabilitation projects, as they are subject to project specific conditions that preclude or constrain the requirements of the guidelines. The application of the guidelines to these projects is at the discretion of the Engineer, and Designers must confirm the limits of the project's Design scope and the appropriate design requirements with the Engineer before initiating the work. As the Design is advanced, the Designer must advise the Engineer of potential impacts to existing infrastructure that may impact project scope, schedule and/or budget, and seek direction from the Engineer before proceeding.

Any modifications to structural components that can reasonably affect structural integrity must be reviewed by a Structural Engineer in writing and subsequently approved by the Operator prior to completion of the Design.

When developing specifications for a renewal/rehabilitation project to be constructed at an existing station or any public LRT realm, the Designer must include a requirement in the specifications for the Contractor to provide a construction and public access plan. This plan must be circulated to the Operator for review and approval. The plan must delineate the construction zones from public areas and provide details related to working hours and duration of impacts.

1.3.4 Quality

The Designer is responsible for the quality of the Design and to ensure that all design disciplines are integrated. The Designer must submit a Design Quality Management Plan (DQMP) to the Engineer for review and acceptance. The DQMP must describe the process and the responsibility hierarchy within the Designer's organization for dealing with quality assurance, as well as the process for quality control. The DQMP must include sample check sheets for documenting checks made on all Design deliverables.

1.3.5 Service Life and Design Life

Service life is the time during which a component of the LRT System is expected to provide its desired function given a specified level of maintenance. Non-replaceable components must have a service life to match that of the associated structure, component, or system. Replaceable components must have a service life consistent with the schedule of maintenance and replacement specified during the design phase.

Design life is the period of time during which a component of the LRT System must perform its intended function without requiring replacement. Design should generally be conservative and use materials and products intended for heavy, prolonged use. In the application of materials and products, the Designer must strive to design infrastructure with minimal maintenance requirements and recommend maintenance procedures that are safe and convenient to implement.

The Designer must use a design life as follows:

- Bridges, elevated guideways, retaining structures, tunnels, and underground Stations – 100 years
- At-Grade and Elevated Stations, as well as other ancillary buildings – 75 years
- Trackway, Overhead Contact System (OCS) bases and poles – 50 years
- Traction Power Substation (TPSS) equipment – 40 years
- All other electrical systems – 35 years
    - Some specific electrical components may have differing design life requirements and are addressed in other chapters (e.g. communications hardware)

These design life requirements are general to the asset categories listed. Sub-components of the asset categories may have a shorter design life that will require the Designer to seek an exception from the Engineer. The design life requirements may also be amended in the Contract Documents.

The Designer must refer to the City's Design and Construction Standards [12] and the City's Facility Consultant Manual [21] for the design life requirements of non-LRT infrastructure.

1.3.6 Accessibility

Universal (Barrier-Free) Design

Inclusion of Universal Design standards in the Design and construction of all City owned and operated facilities is mandated by City of Edmonton Policy C602 – Accessibility for Persons with Disabilities and the City of Edmonton's Access Design Guide. An Urban Style LRT philosophy and SUI principles requires a strong emphasis on providing public facilities with improved Barrier-Free access, safety, interchange functions, and neighbourhood integration. Application of Universal Design principles is relevant to the Design of the entire LRT System, including, but not limited to, the following:

- LRVs
- ETS communication systems and equipment
- All Patron amenities
- Circulation on Platforms and surrounding Station areas
- ETS network interchange accommodations, and connections to Transit Centres and Park and Ride facilities

Regulatory codes and standards for Barrier-Free design outline the minimum requirements to satisfy the AHJ pursuant to the Safety Codes Act [4]. However, in achieving the mandated Universal Design standards, noted above, additional codes or guidelines may also apply.

Refer to Chapter 10, Stations and Ancillary Facilities for Accessibility requirements specific to Stations and other publicly accessible ETS buildings.

Refer to Chapter 14, Urban Integration for Accessibility requirements specific to the urban design of Station areas and interchange infrastructure.

1.3.6.1 City of Edmonton Corporate Accessibility Committee, Accessibility Advisory Committee, and Other Key Stakeholders

The Corporate Accessibility Committee (CAC) is an administrative committee comprised of representatives from all City departments with the key role of ensuring Policy C602 - Accessibility for Persons with Disabilities is implemented and Accessibility principles are incorporated into all City of Edmonton projects.

The Accessibility Advisory Committee (AAC) is a citizen committee which provides advice and recommendations to Council about facilities, infrastructure, programs, services, activities, and policies for the purpose of improving the City's livability, inclusiveness, and Accessibility for individuals with Disabilities.

The Designer must meet the requirements of the City of Edmonton's Access Design Guide and should take advantage of opportunities to incorporate the maximum practicable degree of Accessibility.

The Designer should have the CAC review the Design of all LRT facilities for reasonable Barrier-Free access at all stages of Design as listed below.

- Project/Program development
- Design development
- Tender development
- Substantial completion
- Commissioning

The CAC will liaise with the AAC to inform and obtain input.

In addition to the AAC, Edmonton City Council has also established the Edmonton Transit System Advisory Board and the Disabled Adult Transit Service (DATS) Working Group. Both groups should be considered for review of Accessibility design issues as required.

1.3.7 Sustainability

Portions of the Design may be subject to the City's Climate Resilience Policy C627 [10]. Before beginning the Design, the Designer must confirm with the Engineer which aspects of the Design are subject to Policy C627 and complete the Design accordingly.

1.3.8 Human Factors

In addition to the requirements in Section 1.3.6 all interfaces, spaces, and systems that interact with Patrons, Passengers, Train Operators, and maintainers must be reviewed by a Human Factors Specialist. A human factors assessment will apply theory, principles, data, and methods of design to optimize safety, product design, human capability, human well-being, human-machine interface, maintainability, and overall system performance. The human factors assessment must be based on allowing usage by Patrons, Passengers, Train Operators, and maintainers within the fifth percentile female to ninety-fifth percentile male adult body type ranges.

1.3.9 Maintenance

Other chapters in these guidelines provide information related to LRT System maintenance that must be considered throughout Design development. The Designer must work with the Operator to understand the project's maintenance plan and corresponding Design requirements.

1.3.10 Service Integration

The LRT System must be designed as an integral part of the City's overall multimodal transportation network. Design considerations must be made for efficient interchange of Patrons to and from other transportation modes.

1.3.11 System Integration

Each design discipline must coordinate their Design activities with other impacted disciplines, in particular architectural, structural, electrical, mechanical, track, Traction Power (TP), Signals, and communications. System integration engineering is required to ensure that Station and LRT ROW elements are properly interfaced.

1.3.12 Proven Hardware

The Design must use proven subsystems, hardware, and design concepts. All subsystems and components, such as vehicles, signaling and communications devices, track equipment, TP equipment, and facility components must 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 must apply to spare parts. Waiver of these requirements will be considered only where an alternative subsystem offers substantial technical and cost advantages, is in an advanced stage of development, and has accumulated substantial test data under near-revenue conditions. The variance request process provided in Section 1.3.1 must be followed when requesting a waiver.

Designs and specifications for the LRT System must encourage competitive bidding by established manufacturers of equipment in accordance with current federal procurement guidelines. In some cases, preferred supplier or approved product lists may be included in the Contract Documents at the Owner's sole discretion.

1.3.13 Approved Products

Approved product lists, and a process for product approval provided by the Engineer, must be referenced when developing the Design and Contract Documents. Other chapters in these guidelines provide more specific details on the use of approved products.

1.3.14 Risk Management and Value Engineering

The Designer must participate in risk management and value engineering processes proportional to the size and complexity of each LRT project. The outcome must inform the Design. These processes are typically led by a third party or as directed by the Engineer. They must be conducted in accordance with industry, project management and project delivery best practices.

1.3.15 Systems Assurance

The overarching goal of LRT projects is to provide a safe, reliable, available, and maintainable service for users, operators, and the public that interact with the system. The complexity of LRT projects requires a consistent and practical approach to all hazards, independent of their category type, through an Integrated Hazard Analysis. This consistent approach, referred to Systems Assurance, provides a complete and auditable record of safety measures for the LRT project.

Where practicable, and in consideration of the size and complexity of the system, Designers must develop and execute a Systems Assurance plan that defines the required System Assurance tasks for Reliability, Availability, Maintainability, and Safety (RAMS), Safety Certification, and Systems Audits. The requirements for Systems Assurance will be defined in consultation with the Engineer. Refer to the City's Systems Assurance Guideline for further details.

1.3.16 Safety and Security

The safety and security of Patrons, Passengers, Train Operators, maintainers, and users of other adjacent and crossing transportation modes is paramount. Designers must refer to Chapter 15, Safety and Security for information related to illegal and unintended activities within the Transportation Corridor. Chapter 17, Streets provides information related to safe crossing of, and access to, the Transportation Corridor. Each other chapter contains additional discipline-specific safety and security criteria and considerations.

The Engineer may request a third-party safety audit of the project during Design development as part of the Systems Assurance process. The Designer must support that process and implement any changes in the Design as directed by the Engineer.

1.3.17 Flexibility

The Design must accommodate extensions, facility upgrades, equipment, and any other infrastructure that can foreseeably be impacted by future projects. The degree of flexibility to be incorporated is at the discretion of the Engineer and Operator. Examples of flexibility are:

- The ability for Grade Separated Stations to accommodate connections to future adjacent development
- The sizing of service rooms to handle all necessary equipment, plus planned future equipment
- The provision of electrical load capacity for additional planned loads

1.3.18 Facility Development Review

All LRT facilities and buildings that can potentially be occupied must be designed in accordance with the latest versions of the Alberta Building Code [1] and the City of Edmonton's Facility Design Consultant Manual [21].

The Design of all LRT facilities requires approval by a City permitting officer. The formal approval procedure involves three stages:

1. Development Permit – applied for and coordinated by the Engineer or the Designer, if directed by the Engineer, unless otherwise noted in the Contract Documents. Development permits are not required for LRT facilities within road ROW.

2. Building Permit – includes the approval of the detailed Design and the issuance of authority to commence construction. Unless otherwise assigned or noted in the Contract Documents, the Contractor must apply for and obtain required building permits.

3. Occupancy Permit – where warranted, is applied for by the Contractor as a condition stated in the Contract Documents.

Designers and Contractors should follow an informal process of review and discussion with the Engineer and the Owner's permitting officer prior to making a formal application for a building permit. This should take the form of on-going consultation with the Owner's plan examiners to deal with issues as they arise during the design phases. The objective of the informal process is to streamline issuance of a building permit and minimize the requirement for changes during and after the facility construction contract award.

1.3.19 Land-Use

The Designer must review any available and applicable land-use planning documents to ensure the Design respects surrounding land uses, both existing and proposed. These documents may include, but are not limited to, Area Structure Plans, Neighbourhood Structure Plans, Area Redevelopment Plans, Planning Overlays, and Zoning Bylaws. The Design must account for items related to existing and proposed:

- Urban design themes
- Traffic movement (pedestrian, cyclist, and motor vehicle)
- Utility servicing for titled parcels

- Overall corridor safety
- Noise and vibration
- Appearance of LRT elements
- Access to and from surrounding land uses and other transportation modes
- Business impacts

The Designer must confirm with the Engineer that all relevant and current land use planning documents are being considered through the Design process.

1.3.20 Local Climatic Conditions

Local climatic conditions must be accounted for in the Design and Contract Documents for all components of the LRT project. All civil, systems, and facility related infrastructure must be capable of operating in the City of Edmonton's full range of climatic conditions and must comply with requirements set forth in all applicable codes and standards.

For information purposes only, the following is the typical range of conditions experienced in Edmonton. The Designer must validate the actual range of conditions at the time of Design through Environment Canada (Environment and Natural Resources Canada) as confirmed by the Engineer.

- Temperature Range: -40º C to +40º C
- Average Altitude: 670 m above sea level
- Humidity Range: 0% to 100%
- Sustained Wind Speed: 70 km/hr
- Wind Gusts: 120 km/hr
- Rainfall (average annual): 350 mm
- Rainfall (24-hr maximum): 114 mm
- Snowfall (average annual): 120 cm
- Snowfall (24-hr maximum): 40 cm

Designers must reference the relevant chapters in these guidelines to determine if different temperature ranges must be applied for the design of specific system components and specifying equipment.

Winter

Typical winter conditions are variable and include wet snow in the early or late season, predominantly dry powdered snow mid-winter, and freezing rain as temperatures fluctuate near 0º C.

Summer

Typical summer conditions include rainfall events that can produce surface stormwater flow where the volume of rainfall exceeds the capacity of the piped drainage systems. Storms that produce hail are common, and snowstorms have historically been experienced at the start or end of the summer season. The Design should account for normal and expected accumulations of sand, salt, dust, trash, and leaves on and along the LRT ROW.

Edmonton has a Köppen climate classification Dfb.

1.3.21 Public Engagement

The Engineer will advise which LRT projects require public engagement. The Designer will reference Public Engagement Policy C593 [8] for the requirements and support public engagement accordingly.

1.4 DRAWINGS AND DOCUMENTS

All plans, designs, and drawings, regardless of their stage of development as described below, must adhere to the City's LRT Computer Aided Design & Drafting (CADD) Standards.

1.4.1 Stages of Design and Drawings

The following is a description of each phase of the Design process.

Corridor Study – identifies Transportation Corridors that the LRT will traverse. This study does not define the horizontal or vertical alignment within the LRT corridor. This phase of the project does not produce engineering drawings.

Concept Plan – provides sufficient detail to identify approximate horizontal and vertical track alignments, Station locations, configurations and type, surrounding roadway geometry, major structure locations, TPSS or Utility Complex locations and footprints, and any other elements needed to estimate the project's land acquisition needs. The Concept Plan must be validated with a desk-top review of existing utilities, geotechnical reports, environmental reports, and topographic survey. Decisions related to the conceptual level track alignment and roadway geometry must be informed by the operating and design parameters described in Section 1.2.4, and must be supported by transportation micro-simulation modelling. TPSS and/or Utility Complex locations must be validated with conceptual level TP load-flow assessments. Cost estimates should be accurate to the thresholds in the City's Project Development and Delivery Model (PDDM) requirements.

Preliminary Design – provides adequate detail, typically 30% of full detailed Design, to provide proof of concept, addresses operational and maintenance needs, considers integration with surrounding land uses, determines land acquisition requirements, and undertakes advanced traffic and Train modelling. Preliminary design requires field investigation to support recommendations, including topographic and legal survey, geotechnical investigation, and environmental assessments. Preliminary Design deliverables may form the reference Design for a design-build or public-private partnership project delivery method. Cost estimates should be accurate to the thresholds stated in the City's PDDM requirements.

Detailed Design – provides tendering and construction ready detail on engineered drawings. Cost estimates should be accurate to the thresholds stated in the City's PDDM requirements.

Issued for Tender (IFT) Drawings – detailed Design drawings and specifications which will be used for tendering construction and procuring a Contractor.

Issued for Construction (IFC) Drawings – detailed Design drawings and specifications to be used by the Contractor for constructing the infrastructure.

Shop Drawings – fabrication detail drawings, based on the IFC drawings, produced by the Contractor or its Subcontractors. The Designer must review these drawings and confirm conformance with the IFC drawings. The Contract Documents must define which shop drawings are to be authenticated by a professional engineer.

As-Built Drawings – drawings and other documents prepared by the Contractor that reflect the installed, fabricated, constructed, or commissioned condition of the project. The need for authentication of as-built drawings by a professional architect or professional engineer employed by the Contractor will be determined by the Engineer on a project-by-project basis. Requirements and process for as-built drawings, including any professional authentication requirements, will be described in the Contract

Documents. Specific requirements related to as-built drawings are contained within the City's Standard Record Documents Guidelines for High Floor LRT Projects.

Record Drawings – final set of drawings prepared by the Designer to reflect changes to the Design including all site instructions, addenda to the Design and final as-built drawings. The record drawings must be authenticated by the Designer in accordance with Association of Professional Engineers and Geoscientists of Alberta (APEGA) and Alberta Association of Architects (AAA) recommended best practices. Record drawings must be submitted in the format specified in the Contract Documents. Specific requirements related to record drawings are contained within the City's Standard Record Documents Guidelines for High Floor LRT Projects.

1.4.1.1 Design Drawing Process

Beginning with the preliminary design phase, the Design drawings must include a full table of contents and all anticipated drawings for the project. Drawings must be complete to the level possible at the time of each submission. Incomplete drawings or drawings that have not been provided for a given submission must clearly indicate the design stage when the information will be provided. For example, the Preliminary Design submission for the Communications scope must have placeholder drawings for detailed wiring schematics with clear indication that the information will be provided during the detailed design phase. It is also acceptable for certain information to be provided during the record drawing phase, specifically when the information depends on the as-built condition of the project (eg. conduit routing).

1.4.2 Standard Record Documents

The Contract Documents will provide direction to the Designer for all required post-construction submissions.

For construction phase close-out, the Designer and/or Contractor must provide the Engineer with Standard Record Documents, as described in the City's Standard Record Documents Guideline for High Floor LRT Projects. These will generally include the following and will be specified in the Contract Documents:

- Record drawings
- As-built drawings
- Operation and maintenance manuals
- Shop drawings
- Guarantees or warranties
- Project closeout records and reports

1.4.3 Operation and Maintenance Manuals

The Contractor must prepare and submit Operation & Maintenance (O&M) manuals that provide the Operator with instructions and related documentation regarding operation of, and the maintenance procedures associated with, each system and related piece of equipment that has been supplied and installed on the project. The Contractor must submit the O&M manuals to the Designer and Engineer for their review and acceptance. Manual requirements are provided in the City's Standard Record Documents Guideline for High Floor LRT Projects, which must be included with or referred to in the Contract Documents.

1.4.4 Contractor Requests for Information and Non-Conformance Reporting

The Designer must respond to and address any Request for Information (RFI), related to the Design that has been submitted by the Contractor. The Designer must also report on the acceptability of any technical aspects of Non-Conformance Reporting (NCR) that occurs during the construction phase. The Designer will provide all RFI and NCR documentation to the City upon completion of the project. The details of these processes must be included in the Contract Documents.

1.5 TESTING AND COMMISSIONING

A testing and commissioning plan must be developed for each LRT project, as described in the Contract Documents. The Federal Transit Administration Handbook for Transit Safety and Security Certification [26] must be followed in developing the plan. The general process should be as follows:

- The Designer must draft a testing and commissioning plan to include in the Contract Documents
- The Contractor must finalize the testing and commissioning plan and provide it to the Engineer for approval
- Once approved by the Engineer, the Contractor is responsible for executing the testing and commissioning plan. The results must be authenticated by a commissioning engineer registered with APEGA
- The Engineer, or their representative, must witness the commissioning and if satisfied will accept the results

The exact process is dependent on delivery method and is to be described in the Contract Documents. The City of Edmonton's LRT Testing & Commissioning Guidelines provide additional details on the process.

1.5.1 Facility Commissioning

The process described in the latest version of the City's Commissioning Consultant Manual must be followed when planning and executing the commissioning of new and rehabilitated Ancillary Facilities.

APPENDIX 1A – URBAN LRT CHARTER

Office of the Deputy City Manager
INTEGRATED INFRASTRUCTURE SERVICES

Memorandum

March 30, 2017

To: All Branch Managers

Copy To: Executive Leadership Team

From: Adam Laughlin
Deputy City Manager

Subject: **Urban LRT Leadership Charter**

The City of Edmonton opened its first LRT line in 1978 and was the first city in North America to develop a modern LRT system. The Capital Line, as it is now called, was a suburban LRT system that utilized the best technology of the day. Since the 1970's, low floor LRT vehicles have become more prevalent and this technology has evolved to be the new standard when designing new LRT systems. In addition to technology changes, there has been evolution of thought around how best to integrate land-use and transportation objectives to create communities with more transportation choice, shorter stop spacing and a system that is integrated with the existing road network. This is the transition from suburban to urban LRT design.

As a result of the policy directions set out in *The Way Ahead, The Way We Move, The Way We Grow* and the integrated transit and land use framework, there have been foundational changes in the way LRT systems are designed and built in Edmonton, in alignment with an urban LRT philosophy.

The Executive Leadership Team is dedicated to ensuring the availability and success of sustainable public transportation options and recognizes the significant role LRT plays in this success. The attached Urban LRT Leadership Charter was created to articulate and demonstrate a collective foundational understanding of an Urban LRT System. The document outline roles, ownership and associated expectations, as well as signifies commitment to the associated principles and will be used to guide further LRT planning, design, and construction as the network is expanded.

Efforts are underway to support Branch Managers in cascading this understanding and expectation into the appropriate areas of the organization.

AL/tl

Attachment

Urban LRT Leadership Charter

Edmonton

Dated: February 16, 2017

Edmonton's strategic plan, The Way Ahead, supports a commitment to create a compact, more integrated urban environment where people have an opportunity and choose to use alternative transportation modes. This means designing a rapid transit system that not only serves communities and destinations, but also integrates and identifies with them. To support this, in 2009 as part of the Transportation Master Plan, City Council adopted a long-term LRT Network Plan, which recommends planning and implementing Light Rail Transit in Edmonton in a new way.

An important part of the LRT Network Plan is a change in approach to the overall system style. While elements of the current LRT system can best be described as a "suburban" system, the LRT Network Plan calls for a change in approach to an urban LRT system. Although the LRT system will include high-floor vehicles and low-floor vehicles, all new LRT lines will be designed and constructed with an urban LRT philosophy.

An Urban LRT system means:

- Building smaller scale stations that are spaced closer together to attract new and increase local ridership;
- Integrated roadway and LRT corridors providing better links to a greater number of local and adjacent route destinations, with more direct transit, pedestrian and cyclist connections;
- Less intrusive infrastructure and better integrated into the community (citizen and community perception as attractor nodes, and not divisive infrastructure);
- Low impact in terms of a facility footprint maximizing the available use of public land by design a compact form;
- Operates within a network of multimodal areas with varying degrees of operational priority and is sensitive to local community impacts while continuing to provide a safe environment for citizens;
- Reducing speeds in congested areas to support safe pedestrian-oriented communities;
- Investing in landscaping, streetscaping, and architectural features to improve visual appeal.

To ensure the success of Urban-style LRT in Edmonton, the Executive Leadership team of the City of Edmonton, commit to the following:

- We recognize that Urban LRT is a City Council-approved priority and that all city departments have a role;
- As a transformative project for Edmonton, Urban LRT is owned by the Executive Leadership Team;
- When we speak of Urban LRT, internally or externally, we speak with a unified voice;
- The belief that Urban LRT is about both city building and moving people; and
- We will move forward with Urban LRT based on current policy while keeping our eyes on future changes in technology or business models that may warrant a modification in approach.

Linda Cochrane

Linda Cochrane, City Manager
Office of the City Manager

D Jones

Doug Jones, Deputy City Manager
City Operations

G Klassen

Gary Klassen, Deputy City Manager
Sustainable Development

R Smyth

Rob Smyth, Deputy City Manager
Citizen Services

A Laughlin

Adam Laughlin, Deputy City Manager
Integrated Infrastructure Services

Todd Burge, Deputy City Manager and Chief Financial Officer
Financial and Corporate Services

Carolyn Campbell, Deputy City Manager
Communications and Engagement

APPENDIX 1B – TRANSPORTATION CORRIDOR & OPERATIONS MATRIX

Corridor Type	Traditional Signaling	Traditional Signaling	Traditional Signaling	Modified traffic/train signaling	Modified traffic/train signaling
	> 55 km/h	31-55 km/h	≤ 30 km/h	31-55 km/h	≤ 30 km/h
Semi-Exclusive Corridor					
LRT ROW SEPARATION					
Hard Barrier – Exclusion	Y	Y	N	Y	N
Soft Barrier – Delineation	NA	NA	Y	NA	Y
No Barrier – Limited Access	NA	NA	NA	NA	NA
MOTOR VEHICLE CROSSINGS					
Gates, bells and lights for road crossings	Y	Y	Y	Y	Y
Crossings limited to major arterial roadways only	Y	DHA	N	DHA	N
PEDESTRIAN & BICYCLE CROSSINGS					
Pedestrians are restricted to road crossings	Y	N	N	N	N
Non-roadway crossing with active warning system	Y	Y	Y	Y	Y
Non-roadway crossing with passive warning measures only	N	N	N	N	N
ENFORCEMENT SIGNAGE	Y	Y	Y	Y	Y
Operating cost per kilometre times base cost*	**1**	**1.5x**	**2x**	**1.5x**	**2x**
Shared-Use Corridor					
LRT ROW SEPARATION					
Hard Barrier – Exclusion	Y	Y	N	Y	N
Soft Barrier – Delineation	NA	NA	Y	NA	Y
No Barrier – Limited Access	NA	NA	NA	NA	NA
MOTOR VEHICLE CROSSINGS					
Centre Running – Gates, bells and lights for road crossings	Y	Y	Y	N	N
Side Running – Gates, bells and lights for road crossings	Y	Y	Y	Y	Y
Crossings limited to major arterial roadways only	Y	Y	N	Y	Y
PEDESTRIAN & BICYCLE CROSSINGS					
Pedestrians are restricted to road crossings	Y	DHA	N	Y	N
Non-roadway crossing with active warning system	Y	Y	Y	Y	Y
Non-roadway crossing with passive warning measures only	N	N	N	N	N
ENFORCEMENT SIGNAGE	Y	Y	Y	Y	Y
Operating cost per kilometre times base cost*	**1**	**1.5**	**2**	**1.5**	**2**
Urban Corridor					
LRT ROW SEPARATION					
Hard Barrier – Exclusion	NA	Y	DHA	DHA	DHA
Soft Barrier – Delineation	NA	NA	DHA	DHA	DHA
No Barrier – Limited Access	NA	NA	DHA	DHA	DHA
MOTOR VEHICLE CROSSINGS					
Centre Running – Gates, bells and lights for road crossings	Y	Y	Y	N	N
Side Running – Gates, bells and lights for road crossings	Y	Y	Y	Y	Y
Crossings limited to major arterial roadways only	NA	N	N	N	N
PEDESTRIAN & BICYCLE CROSSINGS					
Pedestrians are restricted to road crossings	NA	DHA	N	DHA	N
Non-roadway crossing with active warning system	NA	Y	Y	Y	Y
Non-roadway crossing with passive warning measures only	NA	N	N	N	DHA
ENFORCEMENT SIGNAGE	Y	Y	Y	Y	Y
Operating cost per kilometre times base cost*	**1**	**1.5**	**2-3****	**1.5**	**2-3****

Notes:

* **Base** : the operating cost per kilometre with an operating speed of 70 kp/h

** **2 - 3 Base**: cost premium is dependent on the actual operating speed (≤30kp/h)

Legend

Y	Acceptable: Condition permitted for given alignment type, operating speed, and signaling type
N	Not Permitted: Condition not permitted for given alignment type, operating speed, and signaling type
NA	Not Applicable: Condition is not applicable (a greater level of protection has already been specified)
DHA	Dependent on Hazard Assessment: Acceptability of condition for given alignment type, operating speed, and signaling type is assessed on a case-by-case basis and subject to the outcome of a hazard assessment and acceptance by the Engineer

APPENDIX 1C – SAMPLE VARIANCE REQUEST FORM

City of Edmonton LRT Design Guidelines

Variance Request Form

Date:	____	**Design Change Number:**	LRTDG_###
Project:	____	**Relevant Design Guideline:**	LRT Design Guidelines
City Project Manager:	____		

Check all that apply

Proposed Addition to Guidelines: ________

Requested Exception from Guidelines: ________

Proposed Change to Guidelines: ________

Description of Addition, Exception or Change to Guidelines:

Proposed Addition: *Give a description of the proposed addition to the existing guidelines.*

Proposed Exception: *Give a description of the exception that is being requested to the existing guideline (exceptions are a one-time only request , not to be used on an ongoing basis).*

Proposed Change: *Give a description of the changes that are being requested to the existing guideline (changes to guideline are to be made when the guideline permanently updated OR additional sections are being added to a chapter(s).*

Justification for Exception / Revision:

Provide a full description of why the request is being made for each proposed addition, exception or change.

Specific Section References:

Name each chapter, section and subsection (as appropriate) that will be affected by the proposed addition, exception or change.

Attachments:

Include and list any relevant attachments that support the foregoing request and justification. Attachments may include drawings, research, analysis, etc.…

Recommended:		**Approved:**	
Consultant PM Name *Consulting Firm*	Date:	*Director Name* ETS Director, LRT Operations	Date:
Consultant Design/Deputy PM Name *Consulting Firm*	Date:	*Project Manager Name* LRT Expansion & Renewal Project Manager	Date:

CHAPTER 2
Vehicles

COE-IM-GUIDE-0017 | v02

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INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

See complete Intent of Use Statement following the cover page.

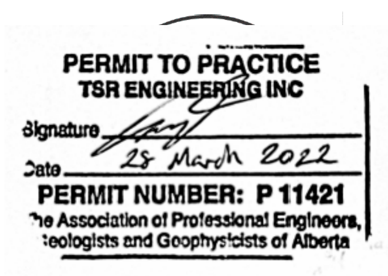
Professional Engineer Seal

2022-03-28
ID # 72332

Carl Wright -- P. Eng. - APEGA

Digitally signed by Carl Wright -- P. Eng. - APEGA
Date: 2022.03.28 17:51:35 -06'00'

Permit to Practice



2 VEHICLES

2.1 INTRODUCTION

This chapter presents general requirements, guidelines, and criteria for designing high floor Light Rail Vehicles (LRV) for the Edmonton Light Rail Transit (LRT) System.

When new vehicles and equipment are acquired, they must meet all requirements related to the operational and physical limitations of existing Stations, LRT Right-of-Way (ROW) infrastructure, track structure, structural loadings of existing bridges, Signals, Traction Power (TP), and storage and Operation and Maintenance Facilities (OMF).

2.2 RAIL STANDARDS AND DESIGN CONSIDERATIONS

2.2.1 Clearance

Chapter 3, Clearances and Right-of-Way, provides criteria for developing Edmonton's LRT design vehicle and clearances that are required for fixed infrastructure to allow unimpeded passage along the Trackway. Design wheel loads and spacing are provided in Chapter 9, Structures.

2.2.2 Urban Integration

LRVs must be designed based on Sustainable Urban Integration (SUI) principles in support of an Urban Style LRT System. Operational safety aspects must be considered given the potential for high numbers of pedestrian, cyclist, and motor vehicle interactions with Urban Style LRT operations.

2.2.3 Vehicle Performance Characteristics

The three specified braking rates used on an LRV are:

- Maximum service braking rate of 1.3 m/s2
- Mandatory braking rate of 1.7 m/s2
- Emergency braking rate of 2.8 m/s2

Passenger loads up to and including AW3 must not have an impact on acceleration or braking performance of the LRV.

Primary LRV braking must be provided by dynamic braking in accordance with EN 13452 [27]. The dynamic braking system must provide maximum service braking rates under all conditions, including a non-receptive Traction Power System (TPS) or when no TP voltage is present. The LRV regenerative braking function must be designed in conjunction with the TPS.

Friction brake equipment must comply with EN 13452 [27].

In accordance with EN 13452 [1], brakes independent of wheel to rail adhesion (electromagnetic brakes) must be provided. The electromagnetic brakes must be provided on all bogies.".

2.2.4 Bogie

LRV bogies must meet the following specifications:

- Bogie axle centre of 1.8 m
- Wheel diameter limits of:

- 720 mm +/- 0.5 mm for new wheels
- 660 mm minimum for worn wheels

2.2.5 Pantograph

The LRV pantograph must comply with EN 50206-2 [28] or IEC 60494-2 [29] and must be capable of operating in either direction at all speeds.

2.2.6 Flammability, Smoke, and Toxicity Considerations

All new LRVs must meet fire, smoke, and toxicity standards as provided in the latest version of ETS-LRV-GTI-0002 [30].

The U2 vehicles (1978-1983) were designed to German standards including Verband Deutscher Electrotechniker (VDE), BOSTrab [31] and Verband Öffentlicher Verkehrsbetriebe (VOV) for fire safety.

The SD160 vehicles are designed to meet the flammability, smoke, and toxicity requirements specified in ETS-LRV-GTI-0002 [30].

2.2.7 Environmental Considerations

LRVs and their subsystems must be designed to provide full functionality for operation in the environmental conditions as provided in Chapter 1, General.

2.2.8 Accessibility

LRVs must meet 49 CFR 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles, Subparts A and D [32].

2.2.8.1 Wheelchair Spaces

At least two passenger doors on each side of the LRV must be designed for wheelchair access and must not be less than 1250 mm in clear width. Wheelchair spaces and access doors should be positioned to provide consistent boarding locations from the Platform regardless of the LRV’s orientation.

Lean bars for standing Passengers must be provided in the space allocated for wheelchairs. Height, size, and material type will be defined during vehicle procurement.

Devices to fix or secure a wheelchair to the LRV are not permitted.

Wheelchair spaces must also be designed to store bicycles, wheeled mobility aids, and child transport devices such as strollers.

Wheelchair spaces must include a control device to allow Passengers to request an extended door closing time, and a pushbutton activated emergency intercom device.

2.2.9 Coupler

Both ends of an LRV must be equipped with an automatically retractable, fully automatic, mechanical or electrical coupler, which is self-centering and heated, plus its associated draft gear system. When not in use, the coupler must be fully enclosed behind an automated front hood. The hood must provide crash energy management and must be designed to minimize injury in LRV to pedestrian, cyclist, or motor vehicle collisions.

In the event of an LRV to LRV collision, the design of the coupler, draft gear, and opening hood must allow the anti-climbers on both LRVs to engage.

Where the designed coupler does not fully retract under the front of the LRV underframe, the coupler and draft gear must incorporate elements that allow controlled break-away and movement to the side of the coupler in a collision.

The coupler must be compatible with the mechanical coupling of the Operator's existing LRV fleet.

2.2.10 Anti-Climber

Anti-climber components must be incorporated into each end of the LRV to prevent over riding in collisions between LRVs. Anti-climbers must be designed to engage with anti-climbers of all existing LRVs.

2.2.11 LRV Loading Requirements

The LRV must be designed based upon the Added Weight (AW) Loadings with the mass of each Passenger and the Train Operator (TO) being 70 kg.

LRV performance design must account for:

- Passenger loading levels up to and including AW3
- Maximum suspension deflections
- The most adverse combination of wheel wear in relation to all infrastructure interfaces, including the Platform to LRV horizontal and vertical stepping distances
- Minimum ground clearance of 50 mm from Top of Rail (TOR)

2.2.12 Weight and Passenger Loading

Minimum Passenger capacity at AW2 is 146 Passengers with a minimum sit/stand ratio of 1:2.

Maximum permitted load on any axle or wheel pair is 12,000 kg at AW4. AW4 is used for structural design loads and not for Passenger loading.

Maximum LRV mass at AW4 must not be greater than 57,972 kg (based on the LRV length from bumper to bumper being 23,604 mm).

A Consist of 5 LRVs must be contained with the limits of the Platforms. Platform lengths are provided in Chapter 10, Stations and Ancillary Facilities.

All equipment must be arranged so that its mass is distributed to maximize wheel to rail adhesion and minimize its propensity to derail an LRV.

Table 2.1 Loading Summary

Loading	Passenger Distribution
AW0	Empty
AW1	Fully seated load + train operator
AW2	Fully seated load + train operator + 4 standees/m^2
AW3	Fully seated load + train operator + 6 standees/m^2
AW4	Fully seated load + train operator + 8 standees/m^2

2.2.13 Crash Energy Management

The crash energy of the LRV must comply with EN 15227 category C-III [33], ASME RT-1, or another international standard approved by the Engineer. The supplier must provide documentation to verify compliance with appropriate standards.

The LRV must be designed using crash energy management principles to absorb the energy in LRV to LRV, LRV to motor vehicle, and LRV to pedestrian or cyclist impacts.

2.2.14 Under-Run Protection

The LRV must be designed to provide under-run protection that prevents persons, animals, and objects from passing underneath the LRV, while interacting with all track types and alignment. Under-run protection must be provided without damaging the LRV or Trackway, and must not interfere with safe LRT System operations.

2.2.15 Anti-Surfing

Features must be included to deter and minimize the possibility of people riding on the external surfaces of an LRV.

2.2.16 Shock and Vibration Considerations

All LRV mounted equipment must be subjected to shock and vibration testing described in IEC61373 [34]. This testing must be performed on the equipment and its associated mounting hardware assembled into its mounting configuration.

2.2.17 Ride Quality

Ride quality of each LRV must be evaluated according to EN 12299 [35] with the Mean Comfort Level (NMV) being no greater than 3.0 when tested with new wheels on representative track for load conditions AW0 to AW3, under all normal vehicle acceleration, braking, and speed conditions.

All LRVs must comply with ISO 2631 [36] for mechanical vibration and shock.

2.2.18 Noise

The method of measurement for internal noise levels within the TO cab and the Passenger compartment must comply with the procedure described in ISO 3381 [37]. Internal noise levels within the TO cab must not exceed values stated in Table 2.2.

Table 2.2 Requirements for Noise Levels Within the Train Operator Cab

Operating Condition of Vehicle and HVAC System	LpAeq,T where T ≥10 seconds
LRV at standstill, ready for operation and HVAC in ventilation or cooling mode at:	
Full-load operation	63 dB(A)
Part-load operation	55 dB(A)
LRV operating at 60 km/h and HVAC in cooling mode at part-load operation	65 dB(A)

Internal noise levels within the Passenger compartment must not exceed the values stated in Table 2.3.

Table 2.3 Requirements for Noise Levels Within the Passenger Area

Operating Condition of Vehicle and HVAC System	LpAeq,T where T ≥10 seconds
LRV at standstill, ready for operation and HVAC at maximum heating	62 dB(A)
LRV at standstill, ready for operation and HVAC in cooling mode at:	
Full-load operation	65 dB(A)
Part-load operation	57 dB(A)
LRV operating at 60 km/h, HVAC in cooling mode at part-load operation:	
(i) At transition, door and running gear areas	70 dB(A)
(ii) All other areas	68 dB(A)

2.2.19 Electromagnetic Interference Considerations

Unless otherwise accepted by the Engineer, the emissions and immunity of vehicle-mounted equipment must conform with EN 50121 Part 3-2 [38], while the emissions of the entire vehicle should conform to EN 50 121-3-1 [13].

LRV procurement must consider all surrounding infrastructure to ensure that vehicle and subsystem immunity to Electromagnetic Interference (EMI) allows for continuous and reliable operation throughout the LRT environment.

The vehicle and its subsystems must be operated based on all external equipment that will be encountered during operations.

2.2.20 Wireless Data Connection

LRVs should provide the capability to integrate to a Wayside wireless network at a maintenance facility to download subsystem diagnostic and Closed Circuit Television (CCTV) data. The wireless network must also provide capabilities for firmware and software updates of onboard subsystems.

2.3 AUXILIARY EQUIPMENT

2.3.1 Equipment Description

ETS operates rail-borne and road-to-rail auxiliary equipment that support ongoing maintenance of the LRT System. As this auxiliary equipment is continuously evolving, the Designer must request a description of the current equipment in use from the Operator to ensure Design compliance.

CHAPTER 3

Clearances and Right-of-Way

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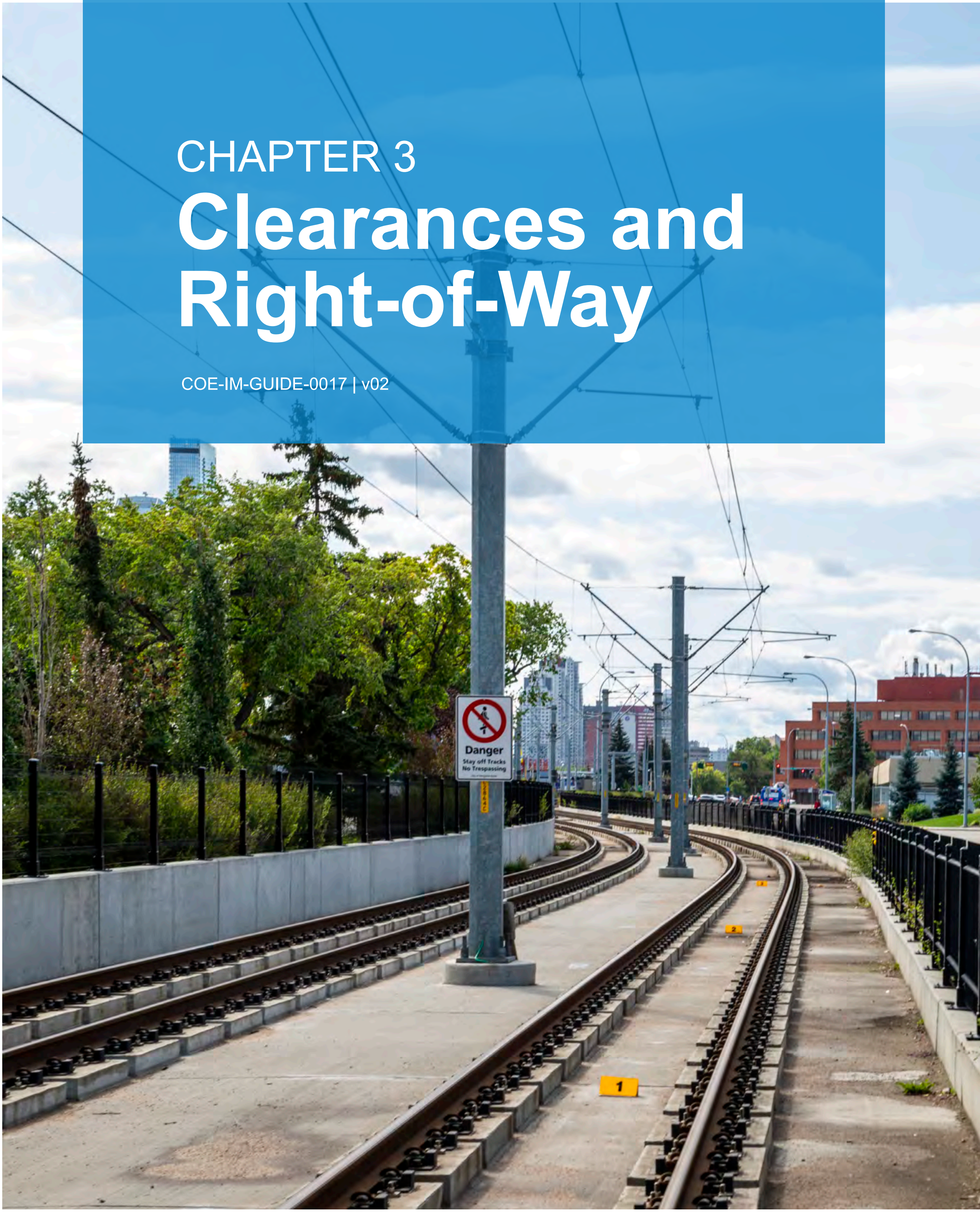

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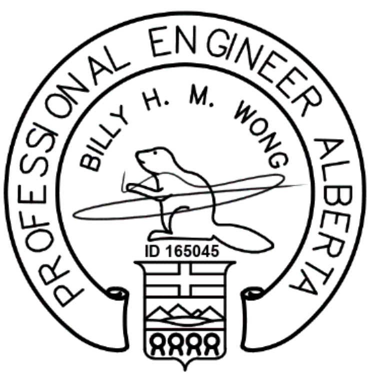
See complete Intent of Use Statement following the cover page.

Professional Engineer Seal



29-Mar-2022

Permit to Practice

PERMIT TO PRACTICE
STANTEC CONSULTING LTD.
Signature ______ ID 67781
Date 29-Mar-2022
PERMIT NUMBER: P 0258
The Association of Professional Engineers and Geoscientists of Alberta

3 CLEARANCES AND RIGHT-OF-WAY

3.1 INTRODUCTION

This chapter presents guidelines and design criteria for clearances and Right-of-Way (ROW) and sets out the acceptable dimensions to provide the required clearances between Trains and adjacent Trackway elements, structures, or obstructions. This chapter also includes description of factors that must be considered by the Designer when defining Light Rail Transit (LRT) ROW limits.

3.1.1 Applicable Codes, Standards, and Regulations

The following references have been used in developing these geometric design guidelines and requirements:

- Manual for Railway Engineering [39]
- Track Design Handbook for Light Rail Transit [40]

3.2 CLEARANCES

Designs must meet or exceed the minimum clearance criteria.

Horizontal clearance dimensions are measured in a horizontal plane irrespective of superelevation in the track. The horizontal clearance is applied along a line projected perpendicularly to the reference track centreline.

Vertical clearance dimensions are measured in a vertical plane to the top of the lowest rail elevation of the reference track.

3.2.1 Design Vehicle

The size of the design vehicle is determined by the maximum dimensions taken from the Light Rail Vehicles (LRV) and all auxiliary equipment used on the LRT System. These physical dimensions include:

- Vehicle width
- Vehicle length
- Vehicle height
- Vehicle wheel base
- Vehicle front and rear overhang over the wheel base

Design vehicle wheel loading and load configuration is provided in Chapter 9, Structures.

3.2.1.1 Design Vehicle Static Envelope

The Design Vehicle Static Envelope (DVSE) forms the basis for the Design Vehicle Dynamic Envelope (DVDE), and is based on the dimensions of the Operator’s rolling stock.

3.2.1.2 Design Vehicle Dynamic Envelope

The DVDE as shown in Appendix 3A Figure 3.1 is the basis for determining the minimum dynamic clearance requirements on a level tangent track for all Trackway elements within the LRT System, with the exception of:

- The minimum clearance between LRV floor elevation and the Platform edge

- Clearance to Catwalks in tunnels

The DVDE must be used to determine the minimum Vehicle Running Clearance Envelope.

3.2.2 Minimum Vehicle Running Clearance Envelope

All LRT Wayside equipment must be placed to not conlict with the DVDE. The Designer must consider the clearance requirements to Wayside equipment at Platforms and around other structures and installations that could encroach into the DVDE.

The Vehicle Running Clearance Envelope (VRCE) represents the space in which no physical parts of the LRT System may exist, other than the design vehicle itself. The VRCE can be calculated as follows:

VRCE = DVDE + SE + CE + TT + SC

Where, VRCE = Vehicle Running Clearance Envelope
DVDE = Design Vehicle Dynamic Envelope
SE = Superelevation Effect
CE = Curvature Effect
TT = Trackwork Tolerances
SC = Structural Clearances

The VRCE is referenced from the centreline of track at the plane of the running rails.

The DVDE is developed on the basis of the design vehicle dynamic movement on level, tangent track. The VRCE must also consider the influence of track alignment geometry, track superelevation, Trackway element installation tolerances, and the specific structural requirements for different Trackway elements.

3.2.2.1 Curvature Effects

Curvature Effects account for the amount of mid vehicle in-swing and end of vehicle out-swing. The amount of in-swing and out-swing can be calculated as follows:

For in-swing:

$$\Delta_i = R(1 - \cos\theta)$$

For out-swing:

$$\Delta_o = ((R - \Delta_i + W/2)^2 + A^2)^{1/2} - R - W/2$$

Where, $\theta = \sin^{-1}(C/R)$
A = extreme end of vehicle/equipment to mid distance between wheel base
B = vehicle overhang from wheel base to the front end or rear end of vehicle
C = half the distance between wheel base
W = dynamic width of vehicle/equipment
R = radius of curve in mm
Δ_i = in-swing clearance in mm
Δ_o = out-swing clearance in mm

This calculation is shown in Appendix 3-A Figure 3.2.

Out-swing is based on a worst-case scenario ignoring the rounded or tapered ends of the design vehicle.

The Curvature Effect through a turnout must also be considered and calculated based on the turnout curve radius.

3.2.2.2 Superelevation Effects

Superelevation Effects (SE) account for the rotation of the vehicle centreline with respect to the vertical axis through the track centreline.

For any given location along a spiral transition zone, the linear superelevation run-off from the circular curve to tangent must be considered in determining the Superelevation Effects.

Appendix 3-A Figure 3.3 illustrates the Superelevation Effect conditions and provides formulae for calculating the displacement.

3.2.2.3 Trackwork Installation and Maintenance Tolerances

The tolerance limits for trackwork are as follows:

- Trackwork installation tolerance of ± 6 mm vertically and laterally
- Gauge maintenance tolerance of ± 3 mm laterally

3.2.2.4 Structural Clearances

The following criteria must used as general guidelines for the Structural Clearance (SC) to adjacent obstructions or Trains:

- Minimum running clearance of 50 mm to non-structural members, such as Wayside Signal equipment and signs
- Minimum running clearance of 50 mm to a designated egress Walkways or Catwalks
- Minimum running clearance of 150 mm along elevated Trackway parapets, walls, structural members, and permanent fixtures
- Minimum running clearance of 150 mm to adjacent Trains

3.2.3 Minimum Vertical Clearance

The minimum vertical clearance distance is governed by the Overhead Contact System (OCS) clearance requirement.

For At-Grade ROW the minimum contact wire height above Top of Rail (TOR) is 4800 mm.

In tunnels and other vertically constrained areas the minimum contact wire height from TOR to underside of the contact wire support structure is 4200 mm.

3.3 APPLICATION OF CLEARANCE CRITERIA

3.3.1 Clearance within LRT Right-of-Way

The minimum distance from centreline of each track to the face of Signal masts and OCS poles on tangent track must be 2070 mm, based on 4.5 m track spacing. Refer to Appendix 3A Figure 3.4.

Where balance weights are located between tracks, the OCS poles must be offset to allow the weights to be centred between tracks. In this case the minimum distance to the weights from centreline of track on tangent track, including an allowance for weight swing, must be 1995 mm.

3.3.2 Clearance to Edge of LRT Right-of-Way

The minimum width of the LRT ROW is defined as an offset from the VRCE as follows:

- VRCE plus 600 mm minimum emergency egress space when LRT ROW is defined by soft barriers
- VRCE plus 760 mm minimum emergency egress space when LRT ROW is defined by hard barriers
- VRCE to back of adjacent roadway curb or back of adjacent sidewalk or Shared Use Path (SUP) for LRT ROW without hard or soft barriers

Non-LRT infrastructure or landscaping is not permitted within the LRT ROW. Buried utilities may be permitted within the LRT ROW subject to the constraints provided in Chapter 16, Utilities and Drainage.

Where the Trackway is located in a ROW shared with an operating railway authority, all clearance requirements of the railway authority must be accommodated in the design of the LRT infrastructure being constructed or modified.

3.3.3 Platform Clearances

Accessibility requirements define the horizontal and vertical gap distance between the Platform edge and the LRV static envelope. Refer to Appendix 3A Figure 3.5. The following criteria must be met:

Horizontal clearances:

- The clearance distance from centreline of track to edge of the Platform must be 1405 ± 6 mm.
- The minimum clearance from centreline of track to a Platform end wall or any obstruction on or above the Platform level must be 1700 mm.

Vertical clearances:

- The elevation at the edge of Platform finished surface above TOR must be 890 +5/-15 mm.
- The Designer must account for any obstructions in the refuge area between the bottom of the Platform and the trackway, including when infrastructure is added into an existing refuge area.

3.3.4 Tunnels

Clearance requirements in tunnels differ based on the tunneling methodology used. Mined tunnels are circular (TBM) or oval (SEM) and require a catwalk, while box tunnels provide a low walkway 200 mm above TOR.

On curved track with superelevation, a tunnel centreline does not coincide with the track centreline and a vertical and horizontal shift of the tunnel alignment will occur relative to the track centreline. The shift in tunnel alignment can be determined based on Appendix 3A Figure 3.3.

3.3.5 Special Clearance Situations

3.3.5.1 Under-Car Clearances

The maximum allowable intrusion of Signals and trackwork equipment mounted between rails at any point along the Trackway is 50 mm above the TOR.

3.3.5.2 Equipment and Pedestrian Safety

A minimum clearance must be provided between OCS contact wires and any areas accessible by the public. Refer to Chapter 6, Traction Power.

3.4 LAND REQUIREMENTS FOR TRANSPORTATION CORRIDORS

In addition to the LRT ROW, the elements and components identified below must be considered by the Designer in determining the required width of a Transportation Corridor that contains an LRT Trackway and Stations. The Designer must confirm the component locations/requirements and related width with the Operator at all stages of Design in determining the required width of a Transportation Corridor.

3.4.1 LRT Elements and Components

Basic requirements to be considered in the design of the LRT corridor include:

- Trackway and trackbed support structures
- Clearance requirements
- Drainage facilities
- Duct banks and vaults
- Catenary poles and related support structures
- Track crossovers
- Wayside equipment
- Signal equipment
- Platforms
- LRT related utilities
- LRV storage tracks
- Building structures required for Station access and stand-alone Traction Power Substations (TPSS) or Utility Complexes (UC)
- LRT related landscaping
- Shared use paths and related landscaping
- LRT Operations and Maintenance (O&M) requirements

Additional requirements based on track geometry include:

- Curvature and superelevation effect on Trains
- Cut and fill embankment side-slopes
- Cut and fill embankment retaining structures

Other factors that may influence required Transportation Corridor width include:

- Noise barrier walls and screen fencing
- Pedestrian grade separation structures
- Transit Centres constructed adjacent to a Station
- Special construction techniques

Clearances and placement for these elements and components must be confirmed with the Engineer and Operator throughout Design preparation.

APPENDIX 3A – FIGURES

CITY OF EDMONTON LRT
DESIGN GUIDELINES

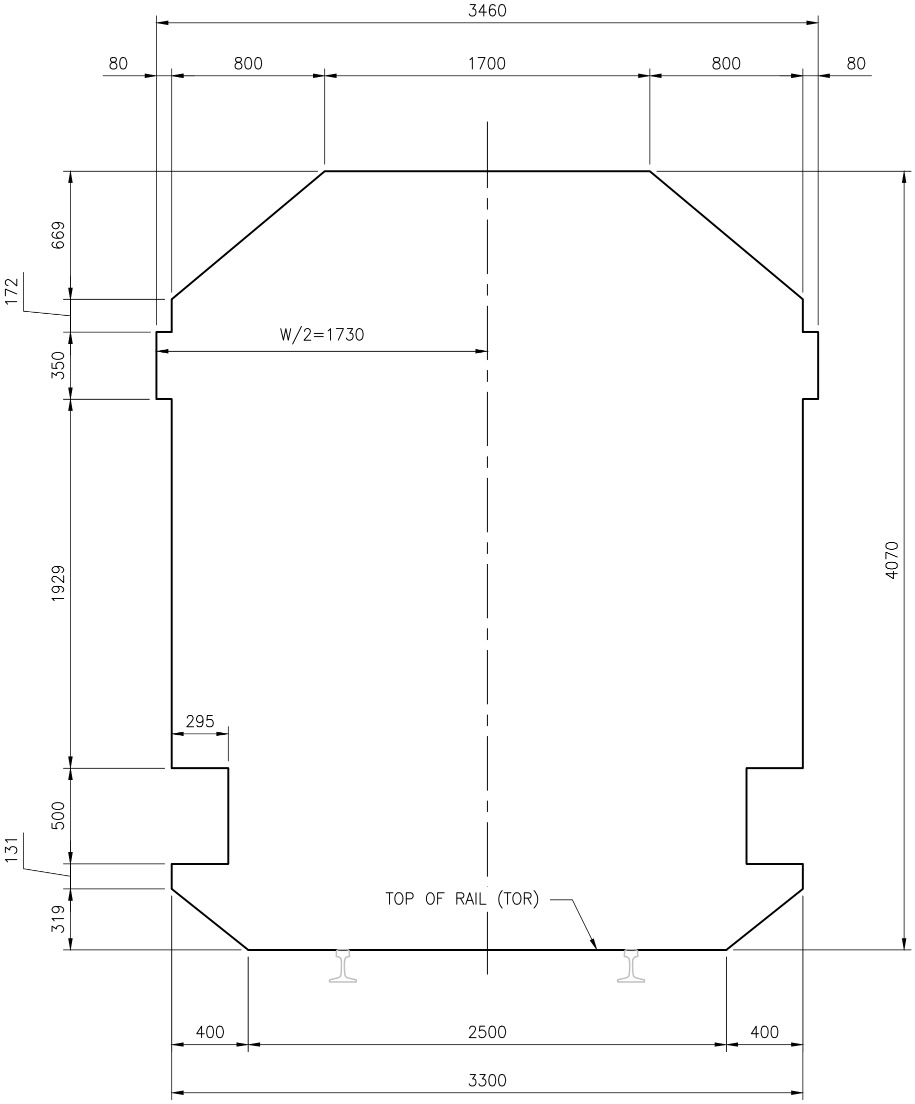
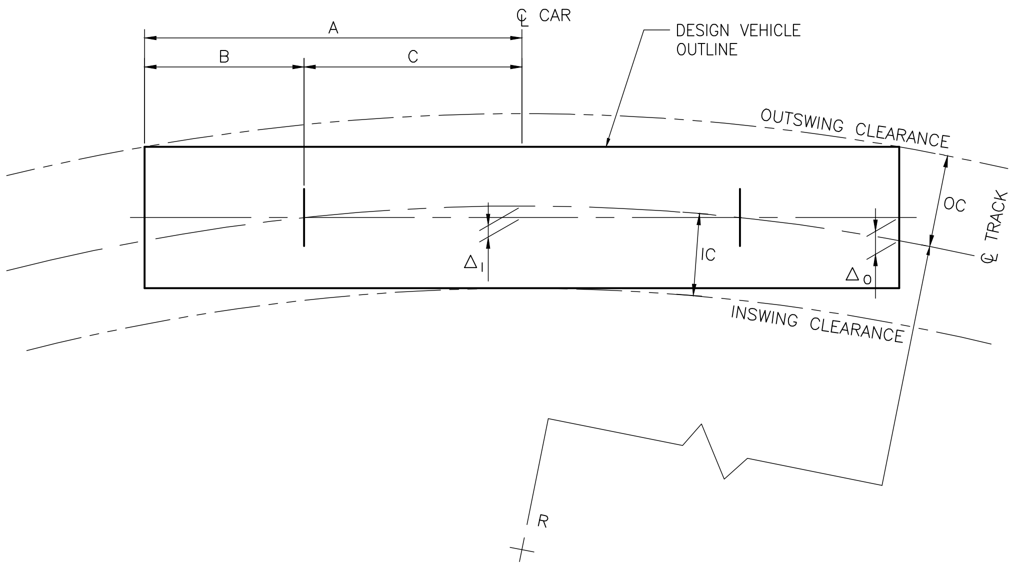


		FIGURE 3.1	CHAPTER 3
		DESIGN VEHICLE DYNAMIC ENVELOPE	CLEARANCES AND ROW
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES



VEHICLE/EQUIPMENT	A (mm)	B (mm)	C (mm)	R (mm)	INSWING Δ_I* (mm)	OUTSWING Δ_O** (mm)	INSWING CLEARANCE (mm)	OUTSWING CLEARANCE (mm)
DESIGN VEHICLE	7942	4082	3860	180	41	132	1771	1862

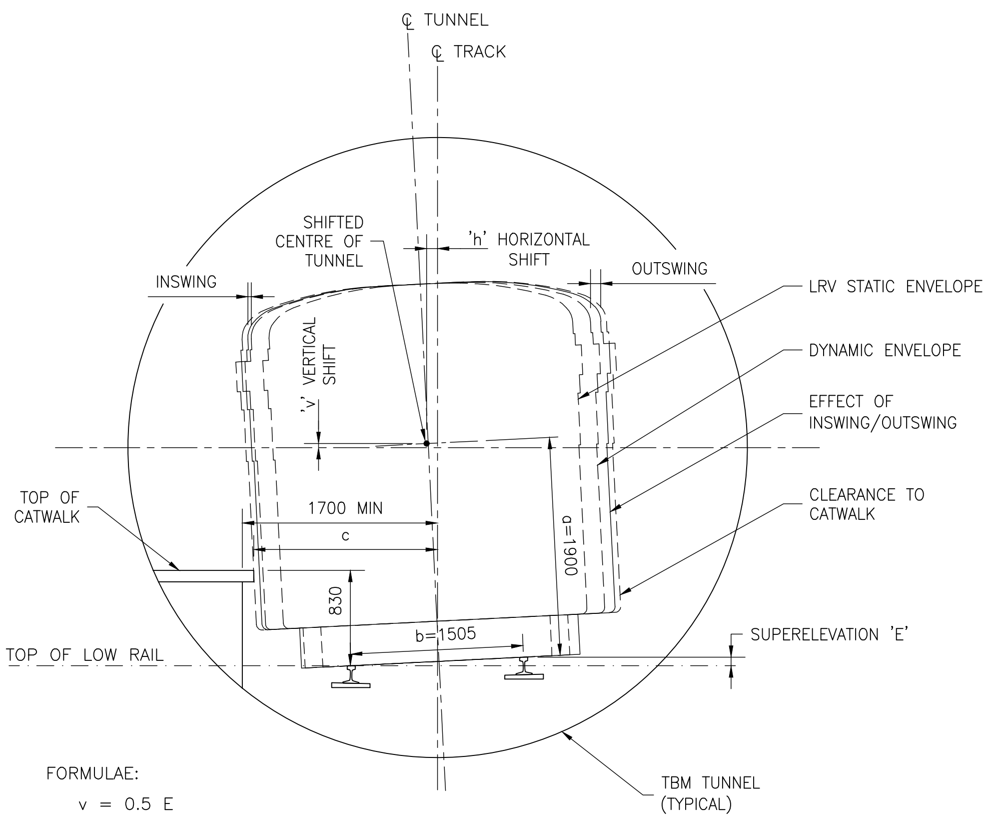
FORMULAE:
*–INSWING CALCULATION
$\Delta_I = R\ (1 - \cos\Theta)$

**–OUTSWING CALCULATION
$\Delta_O = (A / (\cos(\tan^{-1}(A / (R - \Delta_I))))) - R$

WHERE,
$\Theta = \sin^{-1}\ (C / R)$
A = B + C, EXTREME END OF VEHICLE/EQUIPMENT TO MID DISTANCE BETWEEN WHEEL BASE
B = VEHICLE OVERHANG FROM WHEEL BASE TO THE FRONT END OR REAR END OF VEHICLE
C = HALF THE DISTANCE BETWEEN WHEEL BASE
R = RADIUS OF CURVE (IN MM)
IC = INSWING CLEARANCE
OC = OUTSIDE CLEARANCE

Date	Revision	FIGURE 3.2 CURVATURE EFFECTS DESIGN VEHICLE	CHAPTER 3 CLEARANCES AND ROW

CITY OF EDMONTON LRT
DESIGN GUIDELINES



FORMULAE:

$v = 0.5\ E$

$h = \frac{a}{b} \times E$

c = 1/2 LRV DYNAMIC ENVELOPE
+ EFFECT OF INSWING/OUTSWING
+ EFFECT OF SUPERELEVATION
+ STRUCTURAL CLEARANCE TO CATWALK

WHERE
E = SUPERELEVATION OF TRACK
a = HEIGHT OF VEHICLE ABOVE RAIL AT THE VERTICALLY SHIFTED CENTRE OF TUNNEL
b = TRACK CENTRE TO CENTRE DISTANCE
v = VERTICAL SHIFT OF TUNNEL CENTRELINE RELATIVE TO TRACK CENTRELINE.
h = HORIZONTAL SHIFT OF TUNNEL CENTRELINE RELATIVE TO TRACK CENTRELINE.
c = CLEARANCE TO TOP OF CATWALK FROM TRACK CENTRELINE.
1/2 LRV DYNAMIC ENVELOPE = (W/2 = 1459) AT FLOOR LEVEL.

CATWALK TOPPING INSWING/OUTSWING TO BE DETERMINED IN ACCORDANCE WITH 1/2 LRV DYNAMIC ENVELOPE (W/2 = 1459) AT FLOOR LEVEL.

		FIGURE 3.3 SUPERELEVATION EFFECTS ON CURVES	CHAPTER 3 CLEARANCES AND ROW
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

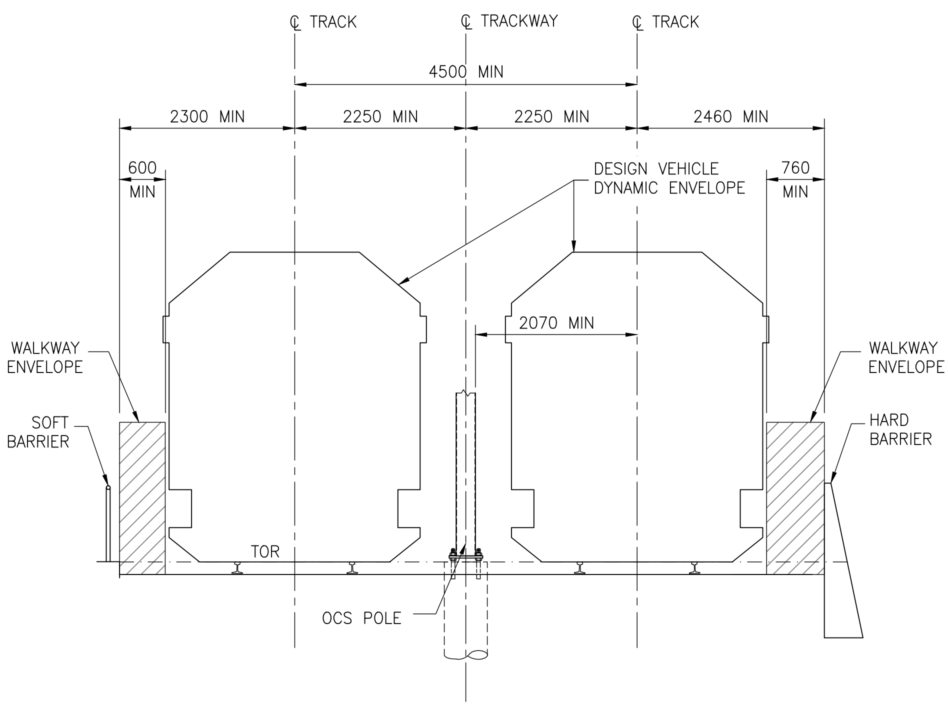


		FIGURE 3.4	CHAPTER 3
		CLEARANCE ENVELOPE LEVEL TANGENT TRACK	CLERANCES AND ROW
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

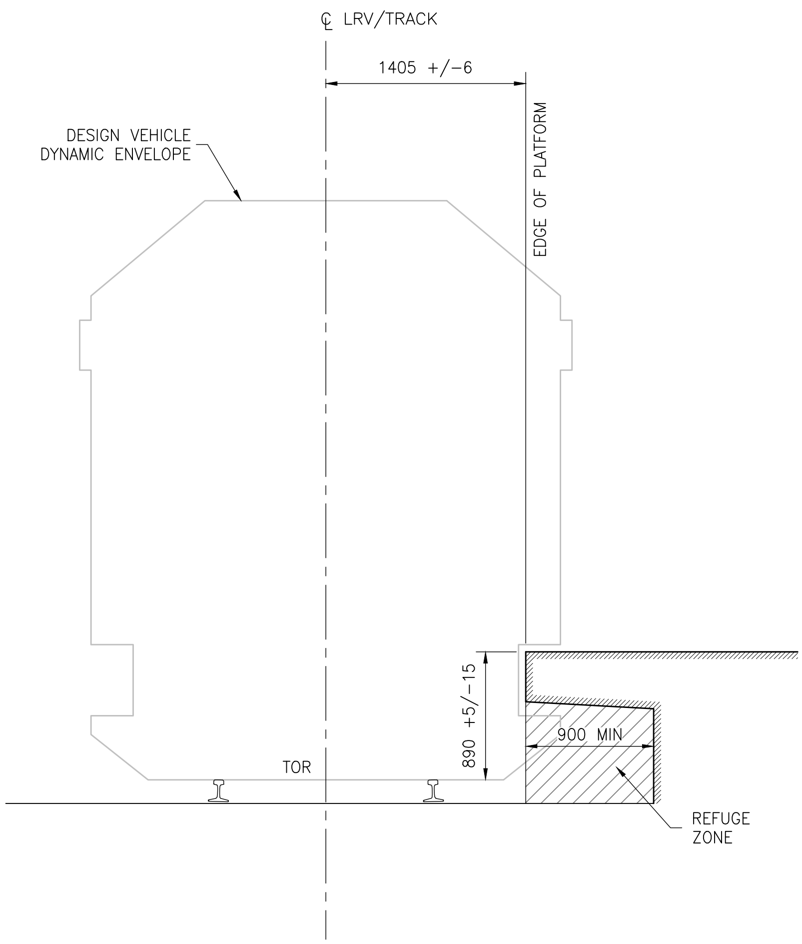
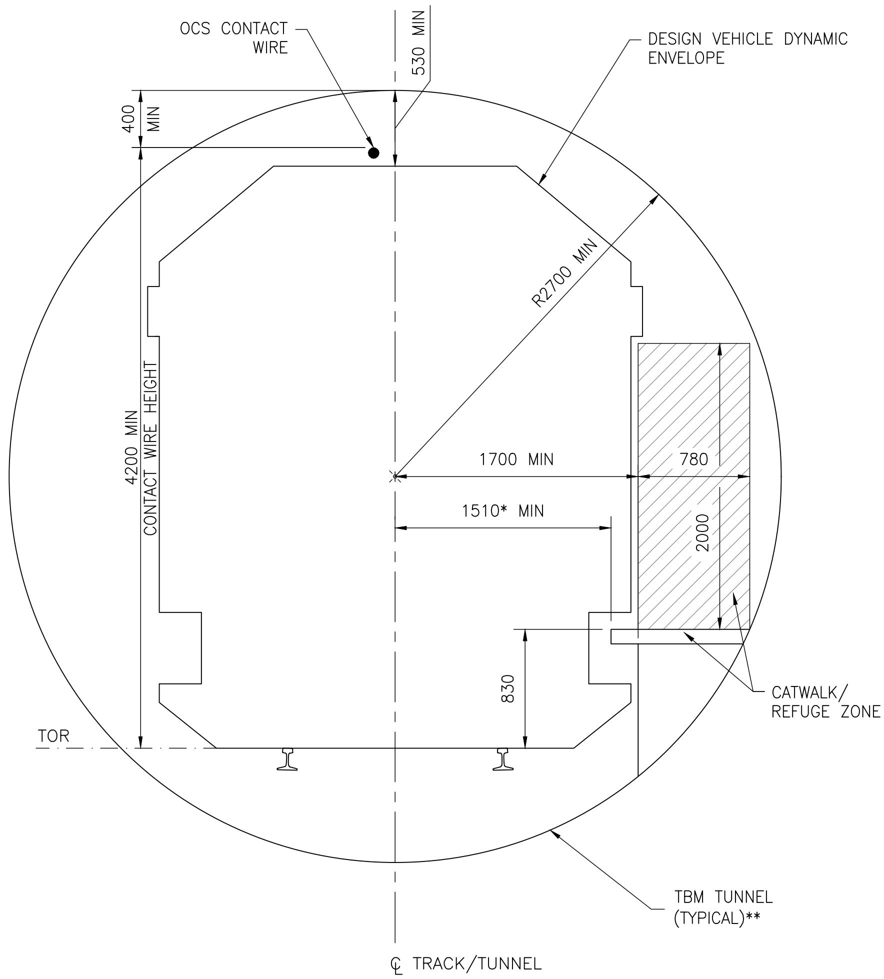


		FIGURE 3.5
		CLEARANCE REQUIREMENTS AT STATION PLATFORM
Date	Revision	

CHAPTER 3
CLEARANCES AND ROW

CITY OF EDMONTON LRT
DESIGN GUIDELINES



NOTES:

*THE ABSOLUTE MINIMUM DIMENSION IS BASED ON TANGENT TRACK WITH NO SUPERELEVATION.

**SEM TUNNEL PROFILE VARIES AND MUST RESPECT VRCE AND CATWALK/REFUGE ZONE

Date	Revision	FIGURE 3.6 CLEARANCE ENVELOPE LEVEL TANGENT TRACK (TUNNEL)	CHAPTER 3 CLEARANCES AND ROW

CITY OF EDMONTON LRT
DESIGN GUIDELINES

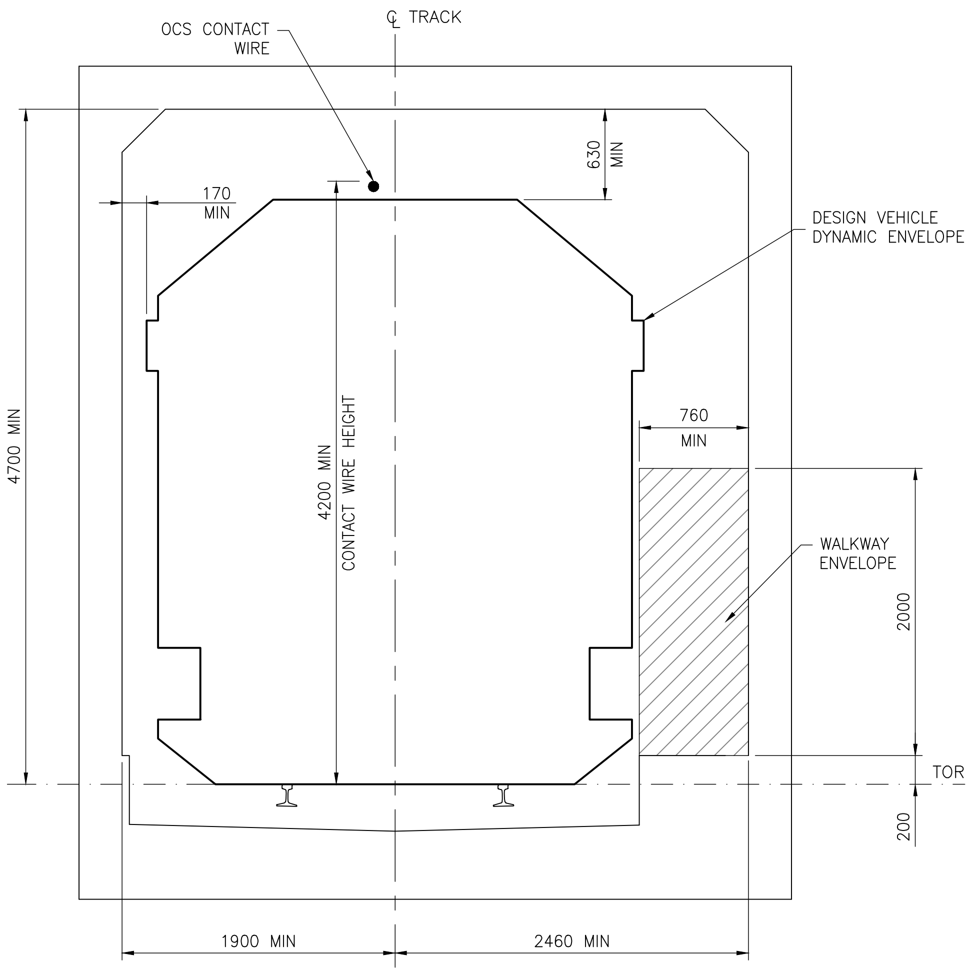


		FIGURE 3.7 CLEARANCE ENVELOPE LEVEL TANGENT TRACK (UNDERGROUND SINGLE BOX)	CHAPTER 3
			CLEARANCES AND ROW
Date	Revision		

CHAPTER 4

Track Alignment

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INTENT OF USE

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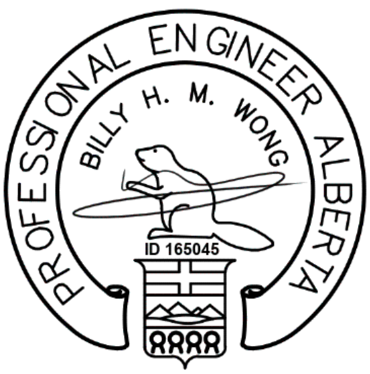

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4 TRACK ALIGNMENT

4.1 INTRODUCTION

This chapter presents guidelines for the geometric design of track alignment for the Light Rail Transit (LRT) System. The minimum and maximum criteria are based on industry practices, Passenger comfort, and safety considerations, and are set as limits that must not be exceeded unless approved by the Engineer.

4.1.1 Applicable Codes, Regulations, Standards and Practices

The following references have been used in developing these geometric design requirements:

- Manual for Railway Engineering [39]
- Track Design Handbook for Light Rail Transit [40]

4.1.2 Design Basis

The Design must consider the design vehicle, overall LRT operations, and maintenance of the LRT System. Factors that will influence design of the track alignment include:

- Cost effectiveness, including maintenance, operating, and Right-of-Way (ROW) acquisition costs
- Light Rail Vehicle (LRV) performance characteristics
- LRV and auxiliary equipment clearances
- ROW restrictions including physical horizontal and vertical constraints
- Geometric design standards and practices
- Public and stakeholder input

4.1.3 Optimization

The objective of track alignment optimization is to have lateral acceleration experienced by Passengers be within acceptable limits and to avoid negative unbalanced lateral acceleration through the range of LRV operating speeds.

Geometric design of the track alignment should be optimized as follows:

- Analyze horizontal and vertical alignment with respect to operational and system requirements
- Develop track charts showing horizontal curve information and vertical alignment profiles
- Calculate maximum allowable unbalanced speed based on curve radii
- Develop a speed profile based on track charts and LRV performance
- Optimize attainable operating speed to avoid abrupt acceleration over short distances
- Adjust actual track superelevation to the optimized operating speeds
- Eliminate negative superelevation conditions

4.1.4 Design Speed

The maximum design speed as dictated by geometric and operational constraints of the track section under consideration and vehicle type is as follows:

- 80 km/h for an LRV Consist on Mainline
- 30 km/h for a work Train on Mainline

- 10 km/h for Yard Track except for vehicle testing track where the maximum design speed is dictated by geometric and safety constraints

Refer to Chapter 1, General for information on operating speeds in the various corridor types.

4.2 HORIZONTAL ALIGNMENT

Mainline horizontal track alignment consists of tangents, circular curves, and spiral transition curves. Circular curves can be further classified as simple, compound, or reverse curves.

4.2.1.1 Reference Lines

The reference line for alignment design must be the track centreline. A separate chainage should be run along the centreline of each track. All track dimensions and clearances must refer to the centreline. The reference track centreline must be tied to the established Survey Control Network (SCN).

4.2.1.2 Track Centres

The minimum track separation on tangent must be 4500 mm at track centres. For track located on curves, the Designer is responsible for verifying that there is no encroachment to the minimum Vehicle Running Clearance Envelope (VRCE) by any ROW elements. The Designer must undertake a dynamic vehicle clearance analysis based on bi-directional Train movement.

4.2.2 Tangent Sections

4.2.2.1 Tangent Length Between Reverse Curves

The minimum tangent length between reverse curves should be the greater of LRV length (25 m) or a travel distance over a 2 second interval.

4.2.2.2 Tangent Lengths Between Curves in the Same Direction

For curves oriented in the same direction, a compound curve or compound spiral should be used rather than a short tangent length between curves. If a tangent section is required, the minimum tangent length requirement for reverse curves applies.

4.2.2.3 Tangent at Stations

Horizontal alignment must be tangent through the entire length of a Station and must extend a minimum of 15 m beyond the end of Platforms.

4.2.2.4 Tangent at Special Trackwork

All special trackwork must be located on tangent track.

For tie and ballast track, the minimum tangent length ahead of the point of switch and beyond the last long ties must be 5 m. If vehicle movement would require a reverse curve, the criterion for tangent length between reverse curves applies.

For direct fixation track, the minimum tangent length ahead of the point of switch and beyond the heel joint of the frog must be 3 m.

4.2.3 Curved Sections

All curves are to be defined by an arc and their radius specified in metres.

4.2.3.1 Circular Curve

The minimum circular curve radius for Mainline Track should be 180 m.

The minimum circular curve radius for Yard Track should be 35 m.

The following must be analyzed when a smaller curve radius is being considered:

- Impact on operating speed, safety, and maintenance
- Mitigation of noise and vibration
- Influence on vehicle dynamic clearances to Trackway elements

4.2.3.2 Spiral Transition Curves

Spiral transition curves must be used on all Mainline track with a radius less than 1500 m. The minimum length of spiral curve must be the greatest of the computed values from Equations 1, 2, and 3 as follows:

- Based on the criterion for the rate of change in superelevation of 30 mm/s in Section 4.2.3.5, the acceptable superelevation, E_a in mm, is computed as:

$$E_a = \frac{Rate \times L_s}{v}$$

Where, *Rate* = rate of change in superelevation of 30 mm/s
v = velocity in m/s
L_s = length of spiral curve in m

and the length of spiral transition L_s in m is computed as:

$$\boldsymbol{L_S = \frac{E_a \times V}{108}}$$ *Equation 1*

Where, V = maximum speed in km/h.

- Based on the maximum acceptable lateral acceleration of 0.067 *g* (*g* = gravitational acceleration) for unbalanced superelevation E_u on a circular curve, and a comfortable rate of change of lateral acceleration of 0.030 *g*/s in Section 4.2.3.5, the length of spiral curve L_s is:

$$L_S = 0.556V \times \frac{E_u}{E_{u\,max}}$$

And:

$$\boldsymbol{L_S = \frac{E_u \times V}{180}}$$ *Equation 2*

Where, L_s = length of spiral curve in m
E_u = unbalanced superelevation in mm
V = maximum velocity in km/h

- Based on twice truck spacing length of the design vehicle, the length of spiral curve L_s in m is:

$$\boldsymbol{L_S = 15}$$ *Equation 3*

4.2.3.3 Compound Circular Curves

Circular curves must be linked by spiral curves conforming to Section 4.2.3.2 provided the compounding ratio between the large radius and small radius does not exceed 1.15. Where the compounding ratio is greater than 1.15, a compound spiral must be used.

4.2.3.4 Compound Spiral

The minimum compound spiral inserted between a pair of superelevated circular curves should be the greater of the following:

$$L_S = \frac{(E_1 - E_2) \times V}{108} \times 2$$ *Equation 4*

$$L_S = \frac{(E_{u1} - E_{u2}) \times V}{108} \times 2$$ *Equation 5*

$$L_S = 15$$ *Equation 6*

Where, L_s = length of spiral curve in m
V = velocity in km/h
E_1 = the larger actual superelevation in the two curves in mm
E_2 = the smaller actual superelevation in the two curves in mm
E_{u1} = the larger unbalanced superelevation in the two curves in mm
E_{u2} = the smaller unbalanced superelevation in the two curves in mm

4.2.3.5 Superelevation

Superelevation must be developed linearly throughout the full length of spiral transition or runoff of circular curves. Superelevation should be achieved by raising the rail farthest from the curve centre whilst maintaining the top of the inside rail at the profile grade.

Superelevation Runoffs

Superelevation runoff for spirals must be accomplished within the length of spiral plus a distance of T_v beyond each end of the spiral transition points as shown in Figure 4.1 and Figure 4.2.

Figure 4.1 Superelevation Runoff for Transition Spiral

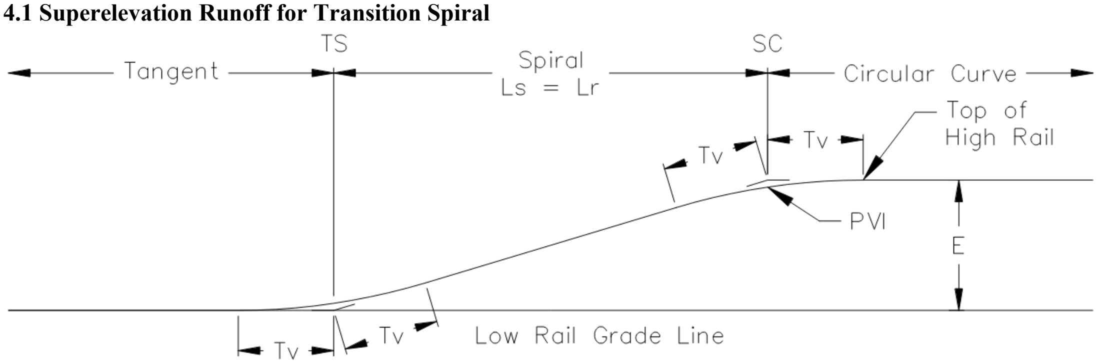
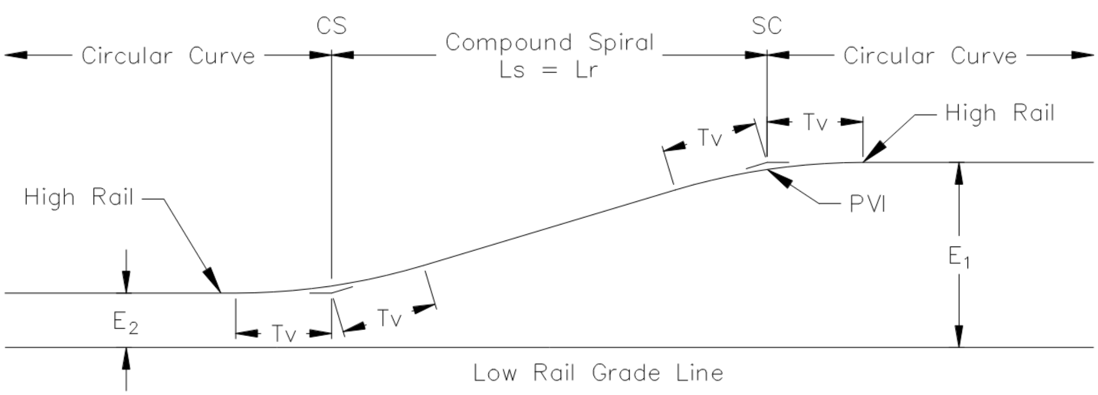


Figure 4.2 Superelevation Runoff for Compound Spiral



A parabolic vertical curve must be used to adjust the runoff elevation at the spiral transition points to avoid creating a kink and inducing stresses in the running rail. The required tangent length (T_v) of the parabolic vertical curve should be between 2 m and 4 m.

Rate of Change in Superelevation

The maximum rate of change of superelevation must be 30 mm/s for the maximum speed of a Train operating on the curve.

Actual Superelevation (E_a)

The maximum actual superelevation (E_a) must be 100 mm.

The adjusted actual superelevation (E_a) must be in increments of 5 mm.

Equilibrium Superelevation (E_e)

The equilibrium superelevation (E_e) is the condition where the wheels are bearing equally on the rail with no lateral thrust and may be determined as follows:

$$F_c = \frac{w \times V^2}{g \times R} \qquad \textit{Equation 7}$$

Where, F_c = centrifugal force acting radially outward, in N
w = mass of vehicle in kg
V = velocity in km/h
R = radius of curve in m
g = acceleration due to gravity, 9.81 m/s^2

and,

$$\frac{F_c}{E_e} = \frac{w}{B} \qquad \textit{Equation 8}$$

Where, F_c = centrifugal force acting radially outward, in N
E_e = equilibrium superelevation (actual superelevation of outer rail in a balanced condition) in mm
w = mass of vehicle in kg
B = 1505 mm (centre of rail head to rail head support),

and,

$$\boldsymbol{E_e = 11.83 \times \frac{V_b{}^2}{R}} \qquad \textit{Equation 9}$$

Where, V_b = speed for balanced superelevation in km/h
R = radius of circular curve in m

Balanced Speed (V_b)

The balanced speed may be determined by substituting E_a equal to 100 mm as follows:

$$\boldsymbol{V_b = \sqrt{\left(\frac{E_a \times R}{11.83}\right)}} \qquad \textit{Equation 10}$$

Where, V_b = balanced speed in km/h
E_a = actual superelevation in mm
R = radius of circular curve in m

The maximum acceptable lateral acceleration for unbalanced superelevation on a circular curve is 0.067 *g* (based on maximum allowable unbalanced superelevation of 100 mm).

Unbalanced Speed (V_u)

An unbalanced superelevation E_u of up to 100 mm may be used in determining an optimal range of safe operating speeds for the alignment under consideration. The maximum allowable unbalanced speed may be determined by substituting E_u equal to 100 mm in equation 11:

$$\boldsymbol{V_u = \sqrt{\left(\frac{(E_a+E_u)\times R}{11.83}\right)}} \qquad \textit{Equation 11}$$

Where, V_u = unbalanced speed in km/h
E_a = actual superelevation in mm
E_u = unbalanced superelevation in mm
R = radius of circular curve in m

Alternatively, the optimal range of actual superelevation satisfying the lateral acceleration criteria may be determined using equation 12:

$$\boldsymbol{Z = 11.83 \times \frac{V_u{}^2}{R} - E_a} \qquad \textit{Equation 12}$$

Where, Z = allowable lateral acceleration in term of g (from 0 to 0.067) in m/s^2
V_u = unbalanced operating speed in km/h
R = radius of circular curve in m
E_a = actual superelevation of outer rail in mm

4.2.3.6 Superelevation Constraints at Special Trackwork

For tie and ballast track, superelevation must not be introduced at a distance closer than 3 m ahead of the switch point or before the last long tie.

For direct fixation track, superelevation must not be introduced at a distance closer than 3 m ahead of the switch point or 3 m beyond the heel joint of the frog.

4.3 VERTICAL ALIGNMENT

Vertical track alignment is comprised of tangential gradients joined together by parabolic vertical curves. The articulating joint movement limits for the current LRV fleet are shown in Appendix 4A Figure 4.1.

For Mainline track parallel to Streets, the gradient may be dependent on the roadway profile to minimize elevation differences between the Street and the trackway. For safety and comfort, vertical alignment at track and Street intersections must provide smooth crossing for both Trains and roadway vehicles.

4.3.1 Reference Lines

Gradients must refer to the horizontal track centreline and top of the low rail for all elevation controls.

4.3.2 Track Gradient

Gradient for all track must be in accordance with the following:

Track Segment	Maximum	Minimum
Mainline	4.5%	0.5%
Stations*	1.0%	0.3%
Storage and Yard	0.5%	0.0%
Shop	0.0%	0.0%

**Notes: Changes in grade within a Station, including 15 m beyond each end of the Platform, are not permitted.*

4.3.3 Vertical Tangent

The length of tangent grade between vertical curves must be a minimum of 25 m.

4.3.4 Vertical Curves

All changes in vertical gradient must be connected using parabolic curves. The minimum length of curve must be the greatest of the computed values from Equations 11, 12, and 13 as follows:

Design Basis	Length of vertical curve (LVC)	Equation
Minimum length permitted	60 m	*Equation 13*
Rate of change in grade	$LVC = A \times K$	*Equation 14*
Vertical acceleration	Crest curves $LVC = 0.0047AV^2$	*Equation 15a*
	Sag curves $LVC = 0.0025AV^2$	*Equation 16b*

Where, A = algebraic difference in grades in percent
V = speed in km/h
K = rate of change in grade

Note:
K = 25 for horizontal tangents or curves with balanced superelevation
K = 50 for horizontal tangents or curves with unbalanced superelevation
K = 15 where speed is restricted to less than 50 km/h

4.3.5 Asymmetrical Vertical Curves

A compound vertical curve with no intervening tangent length between two vertical curves may be permitted where there are existing vertical or geometric constraints. Asymmetrical vertical curves must not be used where a vertical curve overlaps a horizontal curve unless the rate of change (K) in the vertical curve is greater than 50 or if speed is restricted to less than 50 km/h and rate of change (K) in vertical curve is greater than 15.

4.3.6 Vertical Curve Restrictions at Special Trackwork

For tie and ballast track, a vertical curve must not be introduced for a distance closer than 3 m ahead of the switch point or before the last long tie.

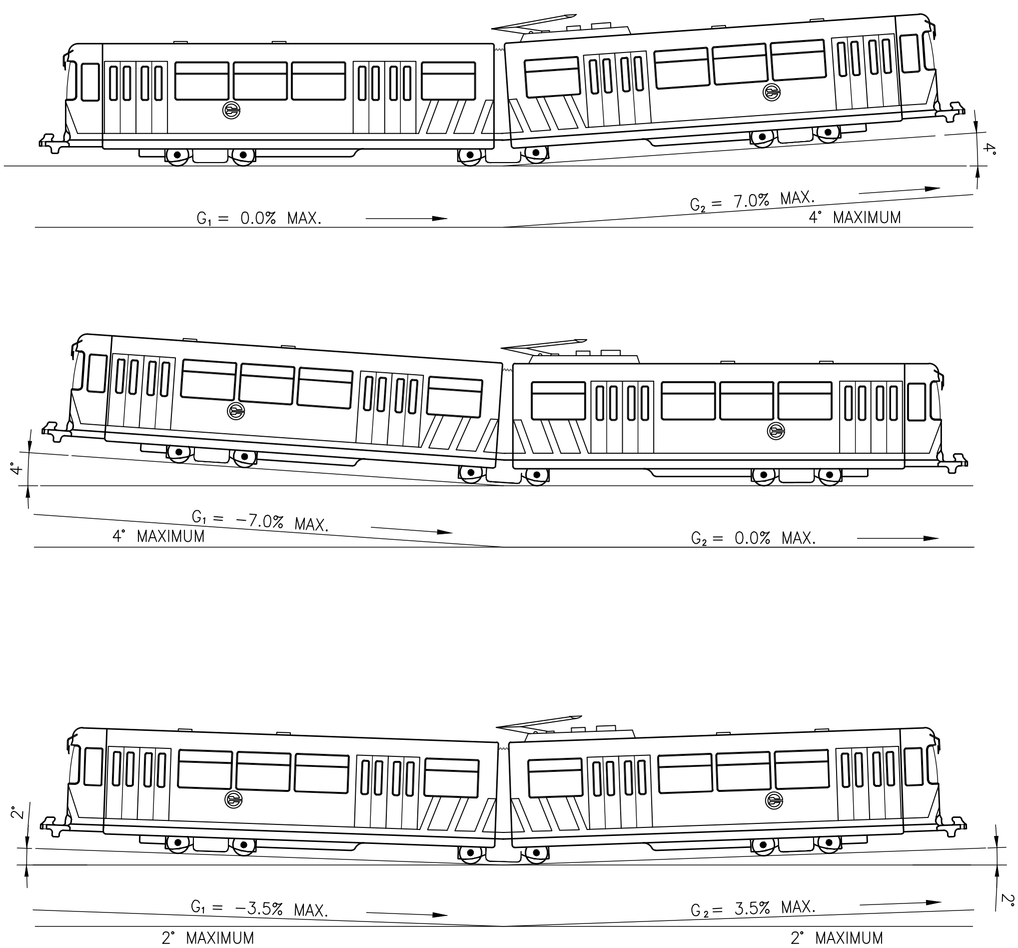
For direct fixation track, a vertical curve must not be introduced for a distance closer than 3 m ahead of the switch point or 3 m beyond the heel joint of the frog.

4.4 COMBINED HORIZONTAL AND VERTICAL CURVES

Overlapping a vertical curve with a horizontal curve produces a twisting (roller coaster) effect and should only be considered where existing constraints make this condition unavoidable. When an overlapping condition exists, the Designer must ensure that the rate of change (K) in the vertical curve is greater than 50 unless the design speed is restricted to less than 50 km/h, in which case K must be greater than 25.

APPENDIX 4A – FIGURES

CITY OF EDMONTON LRT
DESIGN GUIDELINES



$A_{max} = (G_1 - G_2) = 7.0\%$

NOTE:
DESIGN VEHICLE ALLOWS FOR 4° MAXIMUM ANGULAR DEFLECTION AT ARTICULATION JOIN.

Date	Revision	FIGURE 4.1 LRV ARTICULATING JOINT LIMITS	CHAPTER 4 TRACK ALIGNMENT

CHAPTER 5
Trackwork

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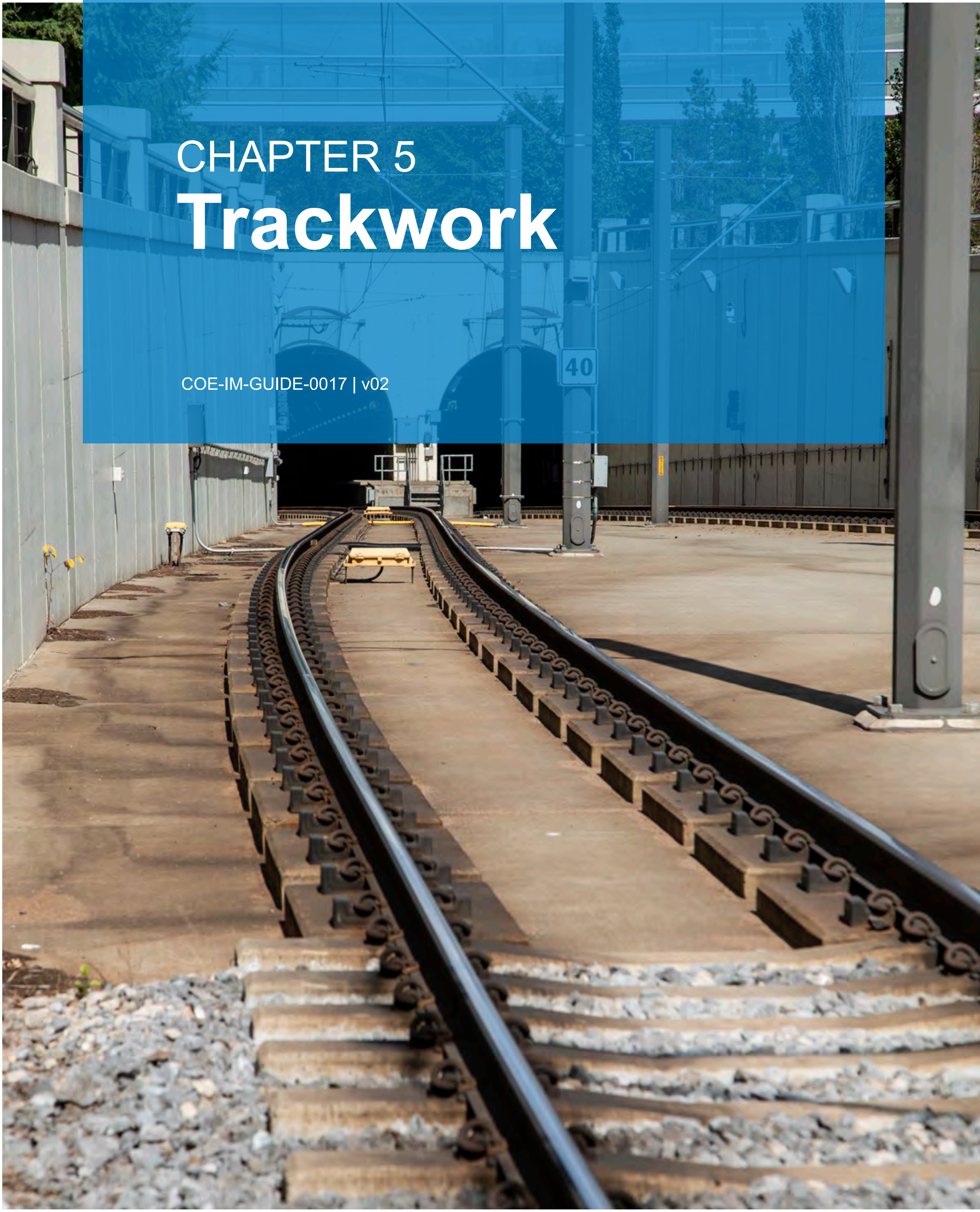

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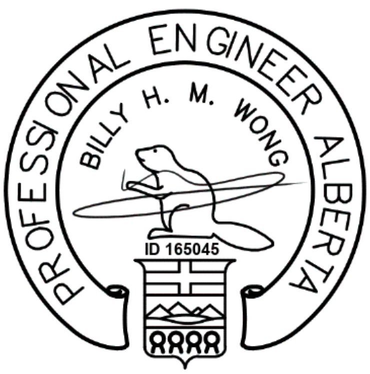

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5 TRACKWORK

5.1 INTRODUCTION

This chapter presents guidelines for the design of track and trackwork components for the LRT System. Track and related track components include rail, special trackwork, support structures, fastening devices, and related hardware.

Technology and products proposed in the trackwork Design must be proven for a minimum of two years of revenue service in an existing cold weather LRT System with similar Operations and Maintenance (O&M) requirements to Edmonton's LRT System. The proposed technology must be compatible with the Operator's existing technology.

5.1.1 General Standards and System Requirements

The trackwork Design must provide the LRT System with continued acceptable performance, and abide by the following principles:

- Minimal changes from the design of the existing system
- Design compatibility with existing trackwork components
- Interchangeability
- Modular design
- Use of off-the-shelf components
- Maintainability
- Availability and reliability

A spare parts list for each trackwork component must be submitted to the Engineer for acceptance, in consultation with the Operator.

5.1.2 Track System Classification

The LRT System includes the following track classifications:

- Mainline Track
- Pocket Track
- Yard Track
- Shop Track

5.1.3 Applicable Codes, Standards, and Regulations

All trackwork must be designed in accordance with current governing codes, regulations, standards, and practices including but not limited to:

- American Railway Engineering and Maintenance Association (AREMA) [39]
- American Society for Testing and Materials (ASTM)
- Canadian Standards Association (CSA)
- Transportation Cooperative Research Program (TCRP) [40]

Track design must consider the design vehicle size, load, performance, and dynamic clearances as provided in Chapter 2, Vehicles and Chapter 3, Clearances and Right-of-Way.

5.1.3.1 Design Speed and Design Wheel Load

All track must be designed for the maximum design operating speeds, dictated by the geometric and operational constraints, as follows:

- The maximum design speed for Light Rail Vehicles (LRV) on Mainline track is 80 km/h
- The maximum design speed for a work Train on Mainline track is 30 km/h
- The maximum design speed for LRVs or auxiliary equipment on Yard Track is 10 km/h
- The maximum design wheel load of an LRV is 5800 kg
- The maximum design wheel load of a work Train is 8000 kg

Refer to Chapter 9, Structures for details on wheel loading for the design of structural elements.

5.1.3.2 Minimum Track Separation and Fouling Point

Minimum separation between track centres is provided in Chapter 4, Track Alignment.

Fouling point restriction based on the Vehicle Running Clearance Envelope (VRCE) of bi-directional Train movement for all Trackway elements must be considered in the Design.

5.1.3.3 Track Gauge

Track gauge for all track, including special trackwork must be 1435 mm +3/-1 mm, measured 16 mm below the top of the railhead. Gauge adjustment must be considered in the design of curves on Mainline track to minimize wheel binding. No gauge widening is required on Yard and Shop Track.

5.1.3.4 Trackwork Lateral and Vertical Adjustability

Direct fixation fasteners and concrete ties must be designed to allow for adjustment of newly installed trackwork as described below.

Direct Fixation Fasteners

Lateral adjustment of ±15 mm in increments of 3 mm must be provided. Vertical adjustment in increments of 1 mm to 20 mm must be provided by using steel shims. A maximum shimming height of 25 mm is permitted with a maximum of three steel shims. Shims must not impact the isolation of rail from the direct fixation track structure.

Concrete Ties

Provision must be made to allow for gauge adjustment. Insulators of varying widths are permitted to provide flexibility for gauge adjustment.

5.1.3.5 Rail Cant

Rail cant must be designed as follows:

- Rail cant must be 1:40, unless otherwise specified
- Rail cant on Mainline and Yard Track may be achieved by using canted fasteners
- Rail cant on non-transitional concrete ties must be incorporated in the rail seat area as part of the tie casting requirement
- Rail may have zero cant on embedded track
- Rail in turnouts and Shop Track must be installed vertically with zero rail cant
- Rail expansion joints and lateral deflecting devices must have the same rail cant as connecting rails

Refer to Section 5.1.13 for sliding rail joint requirements.

5.1.3.6 Rail Cant Transition

Rail cant transitioning from zero to 1:40 between turnouts and connecting tracks must take place over a minimum 2 m length and a minimum 1.5 m before the point of switch. This transition may be achieved by using tapered shims, elastomeric grout pads, or concrete crossties with built-in variable canted rail seats.

The rail cant transition must not overlap an Insulated Joint.

Rail cant transitioning is not required at the transition point between Yard and Shop Track.

5.1.3.7 Flangeway

Flangeway dimensional requirements are a function of the wheel profile (refer to Appendix 5A Figure 5.1 and Figure 5.2) and the track curve radius. The wheel flange width and the back-to-back wheel flange distance determine the appropriate wheel flange clearance. The flangeway width must consider both LRV and rail-mounted maintenance equipment requirements and pedestrian / shared use crossing safety.

The flangeway width through a frog and the corresponding guard rail must be designed to prevent excessive lateral wheel movement at the point of wheel transfer.

The following are the flangeway requirements for the LRV wheel profile and the standard Association of American Railroads (AAR) wheel profile on the LRT work Train:

- Frog flangeway – 47 mm (width) x 52 mm (depth)
- Guard rail flangeway in special trackwork – 45 mm (width) x 52 mm (depth)
- Restraining rail flangeway in curves – adjustable width to compensate for rail wear and operating speed x 52 mm (depth)
- Pedestrian, cyclist, or motor vehicle crossing flangeway – 65 mm (width) x 52 mm (depth)

5.1.4 Electrical Isolation

The LRT System uses a nominal 670 V Direct Current (DC) power supply. Both rails of the track are used as conductors for the Traction Power (TP) return current. Stray Current must be addressed in the trackwork Design, as discussed in Chapter 13, Corrosion and Stray Current. All trackwork systems in direct contact with the LRV must have provision for electrical isolation from ground as follows:

- Wood ties – electrical isolation is required between the rail and tie
- Concrete ties – the rail base that contacts fasteners on concrete ties must be isolated electrically
- Composite ties – electrical isolation is required between the rail and tie
- Direct fixation track – the rail base that contacts fasteners on a concrete slab must be isolated electrically
- Embedded track – the rail must be isolated from a baseplate or from the base concrete by rail boots or elastomeric materials

Corrosion protection must also be considered at crossings, track structures, and underground utilities along the LRT ROW, where current leakage could cause corrosion of these assets. See Chapter 13, Corrosion and Stray Current for more details.

The grounding system and insulating requirements must be designed and constructed based on a grounding study as discussed in Chapter 13, Corrosion and Stray Current.

5.1.5 Noise and Vibration Attenuation

Trackwork design and selection of trackwork components must consider the following methods for controlling and/or reducing noise and vibration:

- Use of resilient or elastomeric bonded direct fixation fasteners
- Use of resilient rail seat pads for concrete ties
- Use of Continuous Welded Rail (CWR) on Mainline
- Use of rubber rail boots or elastomeric materials for an embedded track system
- Incorporation of track lubricators on curved track with a radius less than 200 m
- Location of turnouts away from sensitive receptors
- Use of trackwork components which incorporate noise and vibration dampening measures
- Rail grinding prior to starting revenue service
- Use of Wayside sound barriers

Additional information on noise and vibration is provided in Chapter 14, Urban Integration.

5.2 TRACK STRUCTURE

Track types used on the LRT System include tie and ballast track, direct fixation track, and embedded track. Concrete, composite, and timber ties are all used on the LRT System, however special trackwork must not be placed on composite ties. Direct fixation track may be either installed on concrete plinths or be slab mounted with elastomeric grout pads. Embedded track is typically designed with the centre of each set of tracks lowered to flangeway depth (partially embedded) except at crossings. The various conditions that inform the choice of track type are presented in this section and are summarized in Appendix 5B.

Alternative track structures must not be proposed in a Design without a proven revenue service record of at least two years on an LRT system with operating conditions similar to the Edmonton LRT System and advantageous in terms of performance, overall cost, and/or maintenance requirements.

5.2.1 Rail Deflection

The Designer must analyze rail deflection to determine the appropriate track structure and to verify the fastener or tie spacing required for the selected track structure design and rail section.

The maximum rail deflection must not exceed 2 mm on Mainline track.

5.2.1.1 Tie Spacing

Tie spacing is dependent on the maximum allowable rail deflection and maximum bearing pressure at the interface layers that makes up the recommended track structure. Tie spacing requirements are as follows unless otherwise specified:

- Concrete tie spacing must be 675 mm
- Composite tie spacing must be 560 mm
- Wood tie spacing must be 560 mm

When non-standard tie spacing is used, the Designer must verify the rail deflection and bearing pressure exerted at the track structure interface. Bearing pressures at the track structure interface must conform to the following AREMA [39] recommendations:

- Concrete tie – bearing pressure at the ballast/tie interface must not exceed 85 psi (585 kPa)

- Composite tie – bearing pressure at the ballast/tie interface must not exceed 65 psi (448 kPa)
- Wood tie – bearing pressure at the ballast/tie interface must not exceed 65 psi (448 kPa)
- Bearing pressure at the subgrade/sub-ballast interface must not exceed 20 psi (138 kPa)

A detailed analysis of allowable bearing capacity must be undertaken to determine the granular depth (ballast and sub-ballast) required for the allowable load to be transferred to the subgrade.

5.2.1.2 Fastener Spacing

The length between direct fixation fasteners on concrete slabs or plinths must not exceed 750 mm. On curved track the fasteners must be installed radially from the centre of the curve.

5.2.2 Track Applications

5.2.2.1 Wood Tie and Ballast Track

Softwood tie and ballast track should be used for Yard Track. Wood ties are not permitted at any other location on the LRT System.

The rail fastening system must consist of a base plate complete with High Density Polyethylene (HDPE) base plate pads, screw spikes, spring clips, and spring lock washers.

Refer to Section 5.1.6.1 for the spacing of wood ties.

5.2.2.2 Composite Tie and Ballast Track

Composite tie and ballast track must be used for At-Grade road crossings in conjunction with pre-cast concrete crossing panels and should be used at pedestrian / shared use crossings. Composite tie and ballast track must also be used at track transitions on non-embedded Mainline track.

The rail fastening system must consist of a base plate complete with HDPE base plate pad, screw spikes, spring clips, and spring lock washers.

Refer to Section 5.1.6.1 for the spacing of composite ties.

5.2.2.3 Concrete Tie and Ballast Track

Concrete tie and ballast track should be used for At-Grade Mainline track and may be permitted for use on structures or trenched track sections, or for Yard track.

The rail fastening system for precast concrete ties must consist of supplier provided cast-in-place cast iron shoulders, spring clips, rail pads, and insulators for fastening 115 lb RE rail.

Refer to Section 5.1.6.1 for the spacing of concrete ties.

5.2.2.4 Direct Fixation Track

Direct fixation track should be used on structures, in portals, and in tunnels, and must be constructed on concrete plinths. Direct fixation track may be used on At-Grade Mainline track sections when tie and ballast construction is not practicable.

Concrete plinths must be connected to a recess in the concrete base slab with a series of stirrups or by rebar connected to threaded inserts. The top of the concrete plinth must be level with the 1:40 inward rail cant being incorporated in the direct fixation fastener.

Inserts for the direct fixation fastener connections must be cast in the concrete plinth. Fasteners must be connected to the concrete plinth with anchor bolts to match the cast-in-place inserts. Running rail must be fastened to the direct fixation fasteners with spring clips. The installation of the rail on the direct fixation fastener must allow for gauge adjustment in the fastener.

Refer to Section 5.1.23 for concrete plinth and insert requirements.

5.2.2.5 Embedded Track

Embedded Mainline track may be used in Shared-Use Corridors and should be used in Urban Corridors as described in Chapter 1, General.

Embedded Mainline track structures should be constructed by embedding the rail in elastomeric grout in a trough in the concrete Trackway slab.

Embedded Mainline track structures may also be constructed using resilient rubber rail boots surrounded by infill concrete. In this application, the rail should be fastened to concrete in-street ties to secure the track gauge and form an integral part of the embedded track structure.

Refer to Chapter 16, Utilities and Drainage for drainage requirements for embedded track.

5.2.2.6 Embedded Shop Track

Embedded track must be used in maintenance facilities to allow for movement of maintenance equipment across the shop floor.

Rail fasteners for embedded Shop Track must be non-resilient and spaced 1.5 m on centre. The fastening system must be designed to secure rails at the proper gauge, line, and elevation.

Gauge rods must be used to maintain track gauge. Gauge rods must be electrically isolated. Vertical adjustments must be made by shimming.

Embedded Shop Track must be infilled with grout or concrete. The field side infill grout or concrete elevation must be 10 mm below the Top of Rail (TOR).

5.2.2.7 Pit Tracks

Pit tracks must be used when access by maintenance personnel to the undercarriage of an LRV is required.

A pit track system is typically comprised of rails directly fastened to the top of steel I-beams. Removable plates must be installed on the field side of pit tracks to allow access to the undercarriage of LRVs from the side.

5.2.3 Track Transitional Requirements

Design measures must be implemented at interface points between different track structures to counteract the variation in track modulus. The Designer must consider the method of track transitioning wherever there is a change in track modulus.

Track Type	Typical Track Modulus (u)
Wood Tie and Ballast	3,000 lb/in^2 (21 N/mm^2) or greater
Composite Tie and Ballast	3,000 lb/in^2 (21 N/mm^2) or greater
Concrete Tie and Ballast	7,000 – 8,000 lb/in^2 (48 – 55 N/mm^2) or greater
Direct Fixation	10,000 lb/in^2 (69 N/mm^2) or greater
Embedded	10,000 lb/in^2 (69 N/mm^2) or greater

The minimum length of a track transition structure depends on the track structure design and the physical constraints at the interface points.

The track transition must be over a minimum of three ties for all types of tie and ballast tracks.

5.2.3.1 Transition Ties

Transition ties must be used at approaches to bridge structures and at wood/composite to concrete tie interfaces.

5.2.3.2 Transition Slab

Transition slabs must be used for transferring track stiffness from direct fixation track to tie and ballast track, or where space restrictions do not allow transition ties to be used.

5.3 SPECIAL TRACKWORK

Special Trackwork is defined as trackwork structures, trackwork components, or fittings that are normally fabricated in whole, or in part, from regular rolled rail section. Special trackwork may include the following components:

- Turnouts and crossovers
- Diamonds
- Restraining Rails
- Expansion or sliding rail joints
- Lateral restraining devices

5.3.1 General Requirements

All special trackwork must be located on tangent track with constant profile grade. Frogs and switch point protectors must be constructed of manganese.

For Mainline tie and ballast track, special trackwork must use concrete ties.

For Mainline direct fixation track, special trackwork must use a slab mount direct fixation system with elastomeric grout pads.

Embedded turnouts and crossovers are not permitted on Mainline track. In sections of embedded Mainline track, turnouts and crossovers should be designed as slab mount direct fixation track with elastomeric grout pads, although direct fixation on concrete plinths may be permitted.

Turnouts for Yard track must use hardwood ties for wood tie and ballast Yard track installations, and concrete ties when the Yard track is on concrete ties.

In maintenance facilities, switches on the shop floor must be installed as an embedded track system to facilitate access by maintenance equipment and personnel. A minimum tangent length of 17 m must be inserted between back-to-back switch points where there is a reverse movement through turnouts.

5.3.2 Turnouts

5.3.2.1 Turnout Requirements

All new turnout installations on the LRT System must be designed and manufactured to AREMA standards. Table 5.1 presents the maximum allowable speeds through turnouts from the AREMA Manual [39] for standard North American turnouts based on a maximum allowable unbalanced superelevation of 65 mm.

Table 5.1 Maximum Allowable Speeds Through Turnouts

Turnout No.	Location	Allowable Speed
No. 5	Mainline Track where space is constrained by track geometry Yards and service areas	15 km/h
No. 6	Mainline Track where space constrained by track geometry	20 km/h
No. 8	Mainline Track where high speeds are not required through the turnout	25 km/h
No. 12	Mainline Track where intermediate speeds through the turnout may be required	38 km/h

5.3.2.2 Turnout Geometry

Turnout geometry is influenced by the design of switch points and heel spread. The turnout curve radius for any turnout installed as part of Mainline operation must not be less than 50 m.

5.3.2.3 Turnout Location

A minimum tangent length of 5 m must be provided between back-to-back switch points where the turnout movement is in the same direction.

When designing turnouts, the following constraints must be considered:

- Turnouts must not be located within 15 m from the end of a Platform
- Turnouts must not be located on vertical curves
- Turnouts must not be located in superelevated track areas
- Turnouts adjacent to roadway crossings must not be located within 50 m of the edge of a driving lane

The criteria in Table 5.2 are based on acceptable elevation differences across the frog and running rail through the turnout, the type of track structure, and the special trackwork configuration. These criteria must be observed when locating turnouts.

Table 5.2 Criteria for Locating Turnouts on Grade

Classification		Direct Fixation	Ballasted Track
Mainline	Turnout with diverging track running uphill	Maximum 2.0%	Maximum 1.5%
	Turnout with diverging track running downhill	Maximum 2.0%	Maximum 1.5%
	Crossover	Maximum 1.0%	Maximum 0.5%
	Double Crossover	Maximum 0.5%	Maximum 0.3%
Yard	Turnout	Not applicable	Maximum 2.0%
	Crossover	Not applicable	Maximum 0.5%

5.3.3 Crossovers

Crossovers are used to diverge or switch Train movements from one track to another. Single crossovers are comprised of two back-to-back turnouts. Double crossovers are comprised of four turnouts and a diamond. Two pairs of single crossovers must be used instead of a double crossover where space permits.

General requirements for crossovers are the same as those listed for turnouts in Section 5.1.10.

5.3.4 Diamonds

A diamond consists of four wheel-transferring points (or frog points) with the following general requirements:

- Double crossover diamonds must be located on tangent parallel track
- The Designer must consider the proximity of track separation to avoid the Train wheels crossing the unguarded frog gaps of the diamond and turnout at the same time
- Rigid frogs must be used in turnouts and diamonds
- The maximum crossing angle of diamonds on Mainline track must be equivalent to twice the No. 8 turnout angle
- The maximum crossing angle of diamonds on Yard Track must be equivalent to twice the No. 5 turnout angle

5.3.5 Sliding Rail Joints

Sliding rail joints must be provided where structural joint movement is anticipated. Sliding rail joints are installed as a set at each specified location. The orientation of the fixed stock rails and the sliding points are both structure and site specific.

Sliding rail joints are typically placed at the transition from a bridge abutment to the movable bridge deck.

Sliding rail joints must be fabricated from the same rail section as the running rail. The sliding rail joint baseplates must incorporate the same rail cant as the connecting track.

The Designer must evaluate the requirement for sliding rail joints.

5.3.6 Lateral Restraining Devices

Lateral restraining devices must be installed at structural interfaces where track movement is not parallel to the fixed structure.

Rails must be secured against lateral movement at movable structure joints where the direction of rail expansion and joint movements are not parallel.

The Designer must evaluate the requirement for lateral restraining devices at the structural interface.

5.3.7 Restraining Rails

Restraining rails must be installed for all horizontal curves of radius less than 200 m. Restraining rails are installed on the gauge side of the low rail and must be tapered to guide the wheel flange in and out of the flangeway at the beginning and the end of the restraining rail.

The flangeway gap between the running and restraining rails must be adjustable.

5.3.8 Guard Rails

Guard rails must be installed on the gauge side of both running rails on elevated Trackways and on bridge structures. Guard rails may also be required at the approaches to abutments and portals in some circumstances which may include, but are not limited to, proximity of special trackwork, sliding rail joints, horizontal curvature, or the existence of unstable ground conditions. Guard rails may be fabricated using part-worn rail. On direct fixation track, guard rails may be directly fastened to the concrete slab or bridge deck. The centre of the guard rail must be located 300 mm from the centre of the running rail.

Refer to Appendix 5A Figure 5.3 for typical guard rail layouts.

5.4 AT-GRADE CROSSINGS

5.4.1 Requirements

At-Grade road crossings must match approach grade and provide positive drainage away from the grade crossing area. The intersecting roadway must cross as close to a right angle as practicable. The crossing must be level and parallel to the plane of rails, extending a minimum of 1 m from the field side of the tracks and must be located clear of turnouts and ROW equipment.

The following factors must be considered in the design of At-Grade crossings:

- Rail joints must be kept clear of the crossing
- Multiple crossings must have the same grade across all rails
- Flangeways must not allow dirt and debris to pass through to the rail fastening system
- Flangeways must accommodate wheels of the LRV and other rail-mounted equipment
- Crossing material and track structure must mitigate potential Stray Current

5.4.2 Road Crossings

5.4.2.1 At-Grade Road Crossings on Tangent Track

For tie and ballast track, At-Grade road crossings must be constructed on well compacted granular fill. Modular pre-cast concrete planks with rubber rail seals on composite ties must be used. Other At-Grade road crossing structures may be considered upon discussion with the Operator and approval by the Engineer.

For embedded track, the rail must be embedded in a rail trough with elastomeric grout.

5.4.2.2 At-Grade Road Crossings on Curved Track

At-Grade road crossings on curved track with a radius less than 150 m must be constructed as an embedded Mainline track structure. The rail must be embedded in a rail trough with elastomeric grout.

Refer to:

- Section 5.1.7.6 for embedded Mainline track requirements
- Section 5.1.15 for restraining rail requirements
- Section 5.1.37 for track lubricator requirement on curved track

5.4.3 Pedestrian / Shared Use Crossings

For tie and ballast track, pedestrian and shared use crossings must use a modular pre-cast concrete crossing panel design with a surface specific to pedestrians on composite ties.

The use of durable interlocking modular full-depth 100 percent molded rubber panels for fastening onto precast concrete ties may be permitted subject to approval by the Engineer and the Operator. The panels must be provided with a durable slip-resistant surface.

Pedestrian crossing geometry must be evaluated in consultation with the Engineer and the Operator.

5.4.4 Service Life and Maintenance

The service life of a crossing must be a minimum of 25 years.

Ease of maintenance must be considered when designing At-Grade crossings to minimize disruption to road / pedestrian traffic during maintenance. At-Grade crossing panels must be modular and interchangeable.

5.4.5 Corrosion Protection

Boots or shields covering the fastening components must be incorporated in the flangeway on both the gauge and field side of the rail to protect the fasteners from material that may cause current leakage if the rail is not embedded in elastomeric grout.

Grounding at the vicinity of the At-Grade crossing must be considered to mitigate corrosion caused by current leakage. See Chapter 13, Corrosion and Stray Current for more information.

5.5 TRACK COMPONENTS

5.5.1 Running Rail

Intermediate strength control-cooled carbon steel rails with minimum 325 Brinell Hardness, manufactured in accordance with the AREMA Manual [39], must be used for running rails.

The LRV wheel profile is shown in Figure 5.1 and the work train wheel profile is shown in Figure 5.2, both in Appendix 5A.

5.5.1.1 Rails for Mainline Track

Running rail for Mainline track must be rolled 115 lb RE (57.2 kg/m) rail.

If a flash butt welding process is used to form rail strings, the maximum rail string length should be 480 m.

New running rails on Mainline must be CWR. CWR should be properly destressed and laid in accordance with the optimum neutral rail temperature of 17°C to 24°C to minimize the destressing requirement. The Designer must confirm the appropriate rail laying temperature with the Engineer during design preparation.

In tunnel sections, the optimum neutral rail temperature must be verified by reviewing historical temperature records or by monitoring the rail temperatures inside the tunnel.

All running rail must be non-drilled in nominal standard 23.8 m lengths.

Rail used in curves with a track centreline radius of less than 150 m must be pre-curved to match the track centreline radius using an industry accepted hydraulic press method or standard roller bending method.

Field welds of rail must be minimum Brinell Hardness 325 measured on the rail head in the center of the weld (along the longitudinal centerline of the rail head) and must not exceed the hardness of the adjoining rail. No welds are permitted to have hardness values greater than 400 BHN.

5.5.1.2 Rails for Special Trackwork

Rail used for the manufacture of special trackwork on Mainline track must be intermediate strength with minimum 325 Brinell Hardness rolled to 115 lb RE (57.2 kg/m) rail. Welded boltless manganese frogs must be used. In areas where there are high impact loads, rail must be hardened to 360 Brinell Hardness, to a minimum penetration depth of 15 mm below the rail surface.

Asymmetrical rail sections may be used for switch points.

5.5.1.3 Pocket Track, Yard Track, and Shop Track

Rail used for Pocket Track, Yard Track, and Shop Track must meet the following requirements:

- Rail for Pocket Track must be 115 lb RE (57.2 kg/m) CWR rail
- Rail for Yard Track must be 115 lb RE (57.2 kg/m) CWR or bolted rail
- Rail for Shop Track must be 115 lb RE (57.2 kg/m) CWR

5.5.2 Fastening Devices

5.5.2.1 Direct Fixation Fasteners

Elastomeric bonded plate fasteners must be used for direct fixation track. The plate type fastener must meet the following requirements:

- Built-in 1:40 inward cant
- Overall plate thickness of not more than 40 mm, nor less than 35 mm
- Overall plate width of 180 mm ± 10 mm
- Overall plate length of 355 mm ± 10 mm
- Ability to provide lateral rail adjustments of ± 15 mm in increments of 3 mm
- Ability to provide vertical rail adjustments to a maximum of 25 mm by inserting steel shims under the plate
- Vertical spring stiffness of the fastener within the range 17.5 kN/mm to 24.5 kN/mm
- Ability to isolate electrical current from running rail

Direct fixation fasteners must be chosen to:

- Withstand the rail/structure interface forces
- Achieve and maintain the desired rail tolerances
- Prevent rail buckling under high temperatures
- Permit rail to move longitudinally due to structural flexure or thermal expansion
- Withstand wear and fatigue
- Mitigate noise and vibration

- Withstand local environmental conditions

5.5.2.2 Standard Baseplates

Standard steel baseplates are used for:

- Rail fixation on wood or composite ties
- Special trackwork where special baseplates are not required
- Cant transition areas

Standard baseplates must be manufactured from rolled steel plate and must have musters to provide rail seating for 115 lb RE rail. Baseplates must have a minimum of four holes with a diameter of 25 mm to accommodate anchor bolts or screw spikes.

Non-standard baseplates may be designed by special trackwork suppliers to fit the rail base of other rail sections.

5.5.2.3 Anchoring Assemblies

Anchoring assemblies connect a direct fixation fastener to the reinforced concrete structure. A minimum of two anchoring assemblies is required per fastener. Each anchoring assembly consists of a female insert, an anchor bolt, and a spring washer. The anchor bolt must be designed to be in constant tension to preclude the bolt from loosening or being placed in bending under service conditions.

The design of the anchoring assembly must provide the following:

- Adequate concrete embedment depth for the female insert
- Sufficient anti-rotation capability of the female insert to restrain the design bolt torque
- Adequate tensile strength of the anchor bolt to apply a clamping force that will provide resistance against the rail overturning moment

Inserts

Female inserts must be cast directly into the concrete base slab as the hold-down connection for mating anchor bolts. The insert must be designed and installed to match the bearing strength of the plinth or slab, and must be epoxy coated.

Typical insert parameters are as follows:

- Overall block out depth for insert embedment of not more than 140 mm, nor less than 130 mm
- Overall insert length of 105 mm ± 5 mm
- Overall depth of threads of 75 mm ± 5 mm
- Ability to accommodate A325, M22 anchor bolts
- Ultimate tensile strength equal to or greater than the ultimate tensile strength of the mating anchor bolt

Anchor Bolts

Anchor bolts provide lateral restraint against loading. Anchor bolts are also subject to a small amount of upward rail force.

Typical anchor bolt parameters are as follows:

- ASTM designation A325 with a Class 2 thread fit

- Nominal diameter of 22 mm
- Minimum tread engagement of 50 mm with the insert

Anchor bolt length is dependent on the thickness of the fastener, thickness of washer assemblies, and the maximum permissible fastener shimming height. It may be necessary to use different anchor bolt lengths to account for the allowable shimming height as follows:

- Standard length to accommodate shimming heights of up to 12 mm
- Longer length to accommodate shimming heights from 12 mm to 25 mm

Washer Assembly

The washer assembly consists of a flat washer and a spring washer. The flat washer is designed to sit flat against the fastener to provide a full bearing surface for the spring washer and anchor bolt. The spring washer must be designed to keep the anchor bolt in tension at all times. The washer spring rate must be between 1.05 kN/mm and 1.23 kN/mm.

5.5.2.4 Spring Clips

Spring clips are used for both direct fixation track and ballasted track and must have the following characteristics:

- Ability to hold gauge
- Ability to resist rail rollover
- Ability to resist longitudinal rail moment
- Elastic resiliency
- Appropriate toe load
- Electrical isolation

Bolted type clips must not be considered except for special trackwork installations as necessary.

5.5.2.5 Screw Spikes

Screw spikes complete with lock washers must be used to fasten baseplates on wood or composite ties. Screw spikes must be 22 mm x 175 mm. Wood and composite ties must be pre-drilled to accept screw spikes.

5.5.2.6 Steel Shims

Steel shims must be used as required on direct fixation track to raise the rail to its designed vertical alignment. Steel shims are typically produced in 1 mm, 3 mm, 6 mm, 10 mm, and 20 mm thicknesses. Steel shims of 1 mm (20 gauge) and 3 mm (11 gauge) thicknesses must be manufactured from galvanized steel, coating designation G60 (458 g/m^2), in accordance with the requirement of ASTM A527-80. Steel shims of 6 mm, 10 mm, and 20 mm thicknesses must be manufactured from hot-rolled plate steel in accordance with CSA G40.21M, Grade 260. The thickness requirements must include galvanization. Steel shims must be hot dip galvanized in accordance with the latest edition of CSA G164-M. Galvanizing must be applied to a minimum 610 g/m^2 coating on both sides after manufacture. The shape, size, and configuration of the steel shims must conform to the outline of the direct fixation fasteners.

5.5.3 Ties

5.5.3.1 Wood Ties

Wood ties used in Yard Track must be softwood. All wood ties must be pressure treated in accordance with the AREMA Manual [39].

The standard nominal dimensions for wood ties must be:

- Depth – 180 mm (7 in)
- Width – 230 mm (9 in)
- Length – 2600 mm (102 in)

Consideration must be given to isolating the rail from the surrounding track structure in areas adjacent to underground utilities, ducts, and other structures. Insulators must be placed at the base of the tie plate and insulating thimbles must be positioned in the screw spike holes to isolate the screw spikes from the base plate.

5.5.3.2 Wood Special Trackwork Ties

Wood special trackwork ties must be hardwood.

The length of wood switch ties varies according to the layout.

All wood switch ties must be pressure treated in accordance with the AREMA Manual [39]. Consideration must be given to isolating the rail from the surrounding track structure in areas adjacent to underground utilities, ducts, and other structures. Insulators must be placed at the base of the tie plate and insulating thimbles must be positioned in the screw spike holes to isolate the screw spikes from the base plate.

5.5.3.3 Composite Transition Ties

Composite transition ties must be used at transition points between wood and concrete ties. Refer to Section 5.1.8. Composite transition ties must be spaced at 500 mm on centre.

The standard nominal dimensions for composite transition ties must be:

- Depth – 180 mm (7 in)
- Width – 230 mm (9 in)
- Length – varies according to the transition layout

The Designer must give consideration to isolating the rail from the surrounding track structure in areas adjacent to underground utilities, ducts, and other structures. Insulators must be placed at the base of the tie plate and insulating thimbles must be positioned in the screw spike holes to isolate the screw spikes from the base plate.

5.5.3.4 Concrete Ties

Concrete crossties must be mono-block prestressed, reinforced concrete ties conforming to the AREMA Manual [39].

Precast concrete ties must be designed to conform to practices specific in CSA A23 and must provide:

- Cast iron rail seat musters to fit the base of the 115 lb RE rail section
- An inward rail cant of 1:40
- A rail gauge tolerance of ± 1 mm
- A rubberized rail seat pad providing a nominal thickness of 6 mm
- Electrical isolation

Adjustments designed to permit gauge widening may be considered by the Engineer unless otherwise specified.

Tie spacing in curves with a radius less than 300 m must be reduced by 75 mm. A track structure analysis is required prior to making tie spacing adjustments. Refer to Section 5.1.6.1.

5.5.3.5 Concrete Special Trackwork Ties

Concrete switch ties must be used for Mainline turnouts. Concrete switch ties must be customized items specifically designed for a given turnout at a given turnout location to match the special switch plates. Concrete switch ties require precision casting of anchor bolt inserts. The precise layout must be pre-determined by the special trackwork supplier with the concrete tie supplier for tie casting.

5.5.3.6 Composite Ties

Composite ties used on road crossings must be composed primarily of post-consumer recycled HDPE conforming to the AREMA Manual [39].

The standard nominal dimensions for composite crossties must be:

- Depth – 180 mm (7 in)
- Width – 230 mm (9 in)
- Length – 2600 mm (102 in)

The Designer must consider isolating the rail from the surrounding track structure in areas adjacent to underground utilities, ducts, and other structures. Insulators must be placed at the base of the tie plate and insulating thimbles must be positioned in the screw spike holes to isolate the screw spikes from the base plate.

5.5.4 Ballast

Ballast used for tie installation must comply with the requirements of the AREMA Manual [39]. Ballast must be 100% crushed rock that is hard, durable, dense, and angular with sharp corners and a minimum of flat and elongated pieces. Aggregate types must be granites and quartzites. Dolomite must not be used. The ballast specification must provide a 100% crushed ballast conforming to AREMA No. 3 gradation. Ballast must be placed to a minimum depth of 225 mm below the bottom of the tie. Ballast of finer gradation must be used in transition slab area where the limited space between the bottom of the tie and the slab may restrict the effective tamping of ballast.

5.5.5 Sub-ballast

Sub-ballast used for trackwork must comply with the current AREMA Manual [39]. Sub-ballast must have suitable mechanical, chemical, and environmental characteristics and permeability. Crushed stone, crushed gravel and sands, or a mixture of these materials must be used as sub-ballast materials. Sub-ballast must be placed to a minimum depth of 275 mm on top of the subgrade, extending to a minimum of 600 mm beyond the edge of the ballast. The top surface of the sub-ballast must be graded to a minimum 3% cross slope for positive drainage towards the side ditches or sub-drains. The sub-ballast layer must support the dynamic load distributed by the ballast section and be able to effectively transfer the load to the subgrade.

5.5.6 Subgrade

5.5.6.1 Subgrade for Tie and Ballast Track

The width of the subgrade is determined by the width of the ballast layer. The compacted subgrade must sustain a minimum bearing pressure of 138 kPa (20 psi).

Drainage must be provided either through track ditches, intercepting ditches, or a perforated sub-drain system. Refer to Chapter 16, Utilities and Drainage.

5.5.7 Ballast Curb

For Trackway cross-sections where the LRT ROW is confined, the ballast and sub-ballast must be retained by a ballast curb.

5.6 OTHER TRACKWORK MATERIALS

In addition to the major track components described previously, the following devices are typically installed on the LRT System. These devices must be electrically isolated to mitigate Stray Current.

5.6.1 Switch Machines

Switch machines are used on Mainline and Yard Track. All switch machines must be trailable. Switch machines can be both electrically and manually operated as follows:

- Mainline must use electric switch machines
- Manual hand-operated switch machines must be used in yard areas. Manual switch machines may also be installed at staging track and emergency switches where Train switching is not part of revenue service operation

Switch machines must be installed on the field side of turnouts.

The following factors must be taken into consideration when designing the placement of switch machines:

- Size of turnout and crossover
- Clearance requirements
- Housing and space requirements
- Switch rod dimensions and block out requirements
- Switch rod clearance requirements from trackwork components and track structure
- Switch machine mounting
- Distance from public areas to the switch machine

Refer to Chapter 7, Signals for information on control of switch machines.

Access to switch machines for maintenance personnel and their vehicles must be provided. The Designer must coordinate with the Operator to determine the location of these accesses.

5.6.2 Switch Blowers

Switch blowers must be installed at switches located on Mainline track where the Trackway is exposed to snow conditions.

The following factors must be considered in the design and placement of switch blowers:

- Clearance requirements
- Housing and space requirements
- Blow duct dimensions
- Length of the switch
- Operating control requirements
- Noise impact to adjacent land uses

5.6.3 Switch Point Detectors

Switch point detectors must be installed in all switches on Mainline track.

The following factors must be considered in the design and placement of switch point detectors:

- Method to connect the switch point detector
- Provision of proper mounting hole sizes and spacing on the switch points
- Block out requirements

5.6.4 Hold-down Bars

All Mainline switches require hold-down bars to prevent upward movement of the switch points. Hold-down bars are not required on yard switches. Hold-down bars must be incorporated as an integral part of special trackwork fabrication by the special trackwork supplier and be specified during the procurement process.

5.6.5 Roller Plates

Roller plates must be incorporated in all powered switches, as an integral part of special trackwork fabrication by the special trackwork supplier, and be specified during the procurement process.

5.6.6 Switch Point Protectors

Subject to confirmation of requirement by the Operator, switch point protectors must be incorporated in all turnouts where the turnout curve is designated as Mainline operation and the Train movement is predominantly a facing point movement. Switch point protectors must also be incorporated as an integral part of special trackwork fabrication by the special trackwork supplier.

5.6.7 Friction End Stops

Friction end stops must be installed at the terminus of all Mainline track. Friction end stops must be able to attenuate the impact load of a 5-car run-away Train at 15 km/h over a maximum sliding distance of 6 m and be designed to engage the coupler end of the vehicle without contacting the body of the vehicle based on an Engineer accepted LRV loading (AW4). Refer to TCRP 155 [41].

The following factors must be considered in the design and placement of friction end stops:

- Rail mounting requirements for the friction elements on the design rail section
- Required sliding distance beyond the point of impact
- Compatibility with an LRV coupler

5.6.8 Wheel Stops

Wheel stops must be installed at the end of Yard and Shop Track. Wheel stops must be rail-mounted or directly welded onto the railhead and must be able to withstand a 5 km/h impact load (AW0) from a run-away Train.

The following factors must be considered in the design and placement of wheel stops:

- Wheel stop clamping requirements on the design rail section
- Welding requirements
- Vehicle wheel radius and point of impact on the wheel stop

Hinged derails must be specified for installation on storage tracks to protect against run-away vehicles moving onto other tracks.

5.6.9 Rail Lubricators

Rail lubricators must be provided to mitigate noise, vibration, and rail wear in sharp curves with a centreline radius less than 200 m.

The following factors must be considered in the design and placement of rail lubricators:

- Use of biodegradable lubricants
- Ease-of-access by track maintenance personnel
- Installation and maintenance requirements
- Ability to provide remote sensing and diagnostics for system malfunctions
- Vandalism resistance
- Ability to adjust lubricant injection manually
- Ability to operate at -40°C
- Ability to precisely direct lubricant to the gauge face of the rail, TOR head, and the contact face of guard rails
- Ability to maintain electrical isolation

5.6.10 Lateral Track Bracing for Stations

Ballasted Track at a Station must be secured by means of lateral track bracing to prevent movement toward the Platform.

Lateral track bracing for Stations may be fabricated from pressure treated timber. Bracing ties must be braced to the outside face of platform structural concrete.

5.6.11 Rail Anchors

Rail anchors must be provided in special trackwork areas where the track geometric integrity is susceptible to change due to the change in rail axial load created by thermal effects and vehicle dynamic braking.

APPENDIX 5A – FIGURES

CITY OF EDMONTON LRT
DESIGN GUIDELINES

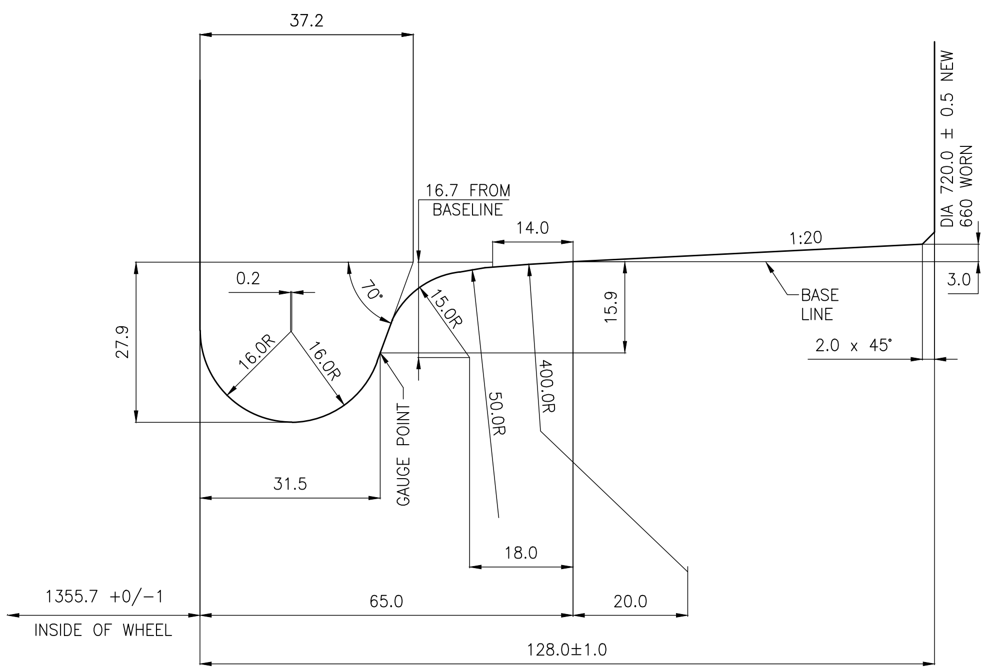

		FIGURE 5.1 LIGHT RAIL VEHICLE WHEEL PROFILE	CHAPTER 5
			TRACKWORK
DATE	REVISION		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

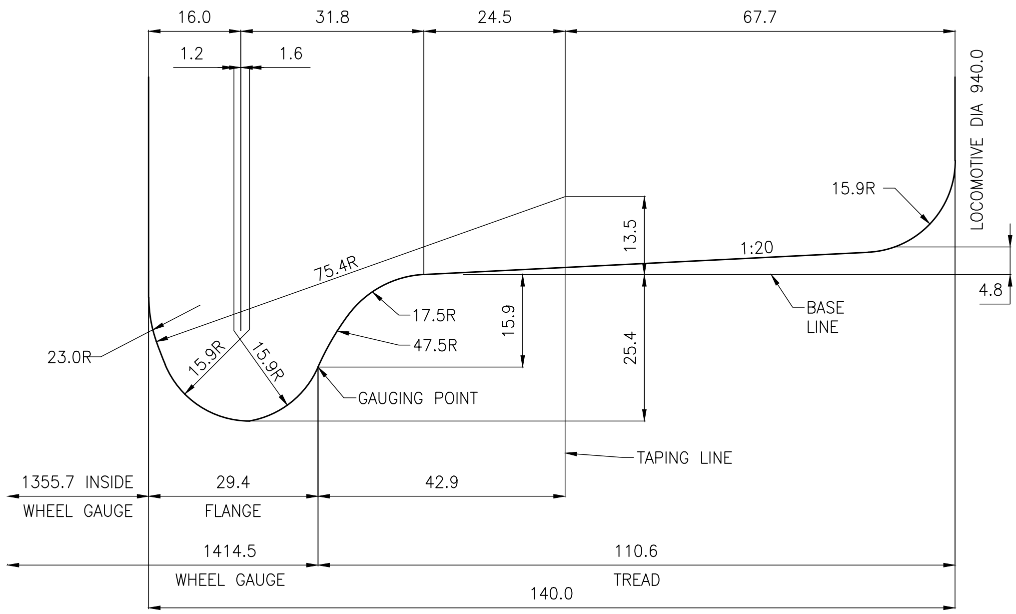

	FIGURE 5.2 WORK TRAIN STANDARD AAR WHEEL PROFILE	CHAPTER 5 TRACKWORK
DATE	REVISION	

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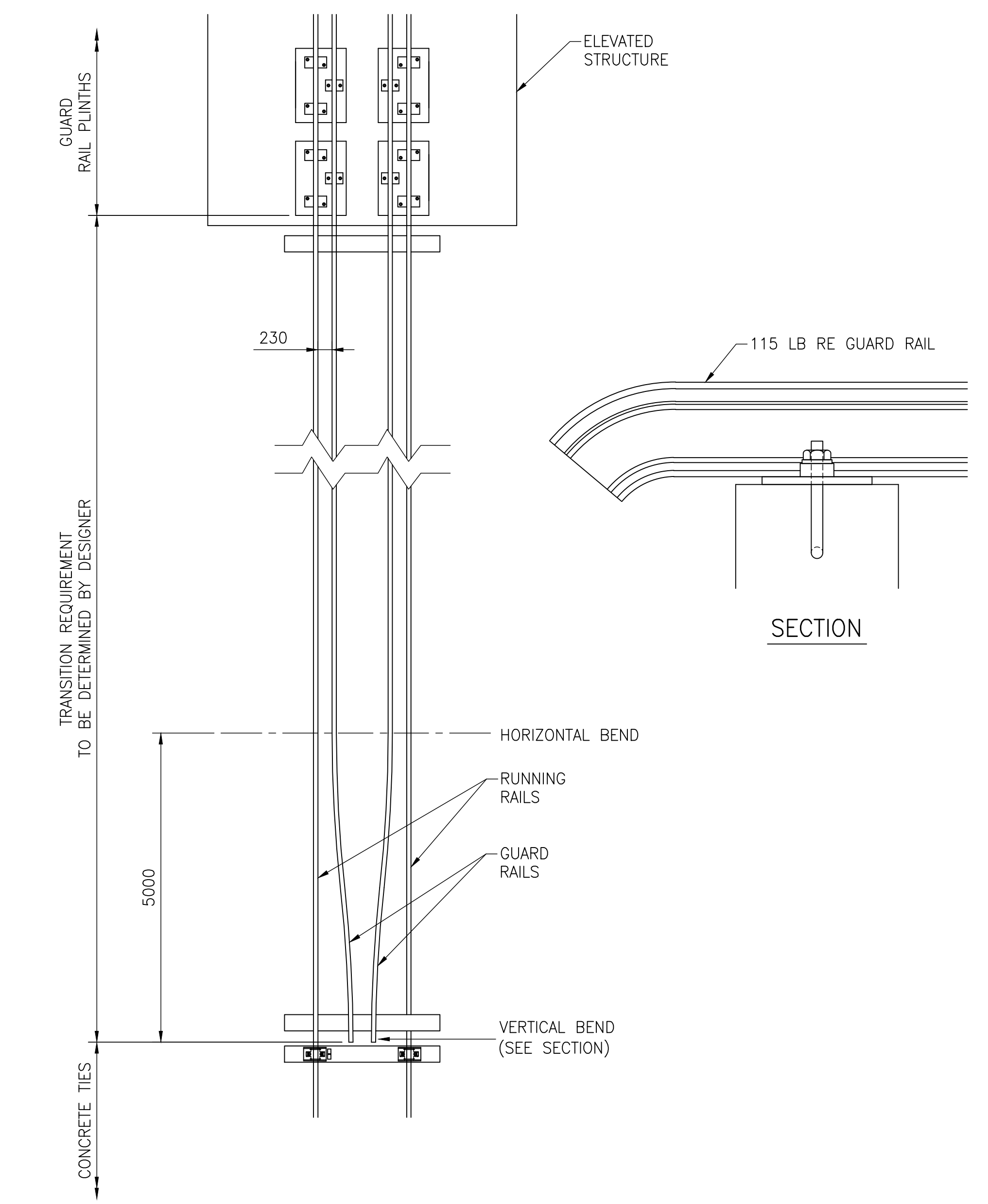

		FIGURE 5.3	CHAPTER 5
		TYPICAL GUARD RAIL LAYOUT PLAN	TRACKWORK
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CHAPTER 6

Traction Power

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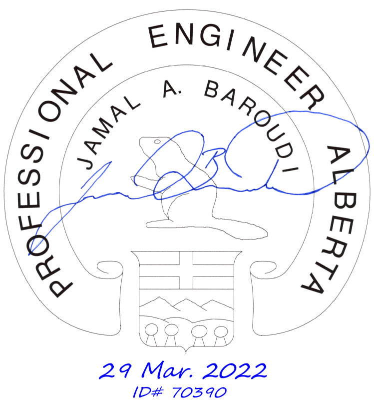

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6 TRACTION POWER

6.1 INTRODUCTION

This chapter presents design guidelines for the Light Rail Transit (LRT) Traction Power System (TPS). The TPS includes Traction Power Substations (TPSS), the Power Distribution System (PDS), the Overhead Contact System (OCS), and associated grounding and bonding.

The Designer must use these guidelines to establish the LRT TPS elements, layout, rating, and configuration.

Facility electrical systems (including lighting) and duct bank design guidelines are provided in Chapter 11, Electrical.

TPSS and Utility Complex (UC) building requirements are provided in Chapter 10, Stations and Ancillary Facilities.

6.1.1 System Description

The TPS is comprised of electrical TPSS (TPSS), a Direct Current (DC) power distribution network, an OCS and a grounding and bonding system that provides safe and reliable power to Light Rail Vehicles (LRVs).

A TPSS converts Medium Voltage (MV) Alternating Current (AC) power from the utility provider to low voltage DC power for Trains. From the TPSS, the PDS delivers positive power to an OCS and collects negative power from rails.

The OCS provides sectionalized DC power to Trains along the entire alignment. Metallic Traction Power (TP) equipment and structures are connected to earth via a dedicated grounding and bonding system for public safety.

6.1.1.1 Future LRT Extensions and System Renewal

Design of LRT System extensions and renewal projects must consider:

- Mitigation of visual impact and achieving an acceptable level of Sustainable Urban Integration (SUI) as provided in Chapter 14, Urban Integration, while considering the corridor type as provided in Chapter 1, General, and while meeting system performance requirements
- Power system capacity to allow for the highest power draw LRV operating at maximum Consist provided in Chapter 2, Vehicles and minimum headways provided in Chapter 1, General
- Half acceleration operations with a TPSS out of service, but accommodating the same Consist length and minimum headways identified for full acceleration operations
- Operational and architectural requirements including factors such as noise, speed, overall appearance of the system, and code clearances as provided in Chapter 14, Urban Integration
- Strategic OCS sectionalizing and switching to optimize track crossover usage during maintenance and service outages
- Power conductor routing to minimize interference with communications systems and the Signal system

6.1.2 Applicable Codes, Standards, Regulations, and Guidelines

Unless stated otherwise, all design activities, equipment and material selection must conform to the requirements of the latest editions of all applicable Federal, Provincial, and Municipal codes and regulations.

AEUC	Alberta Electrical Utility Code
CEC	Canadian Electrical Code [42]
NFPA	National Fire Protection Association
IEEE	Institute of Electrical and Electronics Engineers
CSA	Canadian Standards Association
ASTM	American Society for Testing and Materials

6.1.3 TPS Elements

6.1.3.1 TPSS

A TPSS converts AC power from the utility service provider to DC power for the LRT System, and includes the following primary elements:

- Dual AC power feeds from the utility service provider
- AC switchgear, including an auto transfer system for dual AC power feeds
- TP transformer and rectifier units
- DC switchgear
- 125 V_{DC} protection and control power system
- Positive line and bypass and negative disconnect switches
- AC medium voltage and low voltage cables
- DC positive and negative power cables
- Rail ground switch
- Programmable Logic Controllers (PLCs) TPSS controllers
- Supervisory Control and Data Acquisition (SCADA) systems
- Human machine interface (HMI)
- DC feeder transfer trip system

6.1.3.2 PDS

The PDS connects a TPSS's positive circuit to the OCS and the negative circuit to the rails, and includes the following primary elements:

- DC positive and negative feeder cables
- Positive Feeder Switches
- Positive Tie Switches
- Negative circuit feeder cabinets
- Rail bonding
- Positive booster cables (as required)
- Underground duct banks
- Cable raceways

6.1.3.3 OCS

The OCS provides positive circuit contact for LRVs. It includes the following primary elements:

- OCS poles (masts)
- OCS hardware

- Contact and messenger wires

6.1.3.4 TPS Spare Parts

The Designer must provide a final recommended spare parts list to the Engineer for review and acceptance. Recommended spare parts lists may originate from an equipment supplier but must be reviewed and further developed by the Designer. Spare parts lists should be segregated for each TPS element including TPSS, PDS, and OCS.

The Designer should account for existing system equipment and components during design to minimize system-wide spare parts requirements.

6.1.4 Load Flow Study

A system Load Flow Study must be used to determine the optimum location and rating of TPSS under all operating scenarios such that system DC operating voltages are maintained above the minimum 480 V_{DC} at the LRV pantograph, rail to ground voltage does not exceed maximum permissible limit of 100 V_{DC}, and PDS conductor and OCS wire types and sizes are adequate to carry normal and contingency system load without overheating under maximum ambient temperatures and solar effects. The contact wires are modeled at their maximum cross sectional wear with 30% as the maximum permitted.

Notwithstanding results of the Load Flow Study, the Designer is responsible for confirming that the OCS design temperature range will be adequate for any new installations and suit actual site conditions.

The placement of TPSS must be based on variables and assumptions included in the Load Flow Study.

6.1.5 TPS Loads and Parameters

The design of new TPSS, Right-of-Way (ROW) additions, LRV additions, or operational changes to the LRT System must be preceded by a TPS load flow analysis to simulate the electrical performance of a new or existing TPS using the physical and operational aspect of the proposed additions under multiple operating scenarios. Results of the study must confirm that the power system satisfies the required operational performance criteria with the most economical expenditure of initial capital investment.

General loading requirements, shown in Table 6.1, must be considered in the design of the TPS. These loading requirements are subject to change and must be confirmed with the Engineer during design.

Table 6.1 General Load Flow Vehicle Requirements

	U2	SD 160 (Reduced AC Mode)
Motoring Current Per LRV	560 A_{DC}	900 A_{DC}
Acceleration Current Per LRV	900 A_{DC}	900 A_{DC}
Peak Average Hotel Power	50 kW	50 kW
Minimum Operating Voltage	480 V_{DC}	480 V_{DC}
Absolute Minimum Voltage	420 V_{DC}	460 V_{DC}
Absolute Maximum Voltage	720 V_{DC}	900 V_{DC}

The TPS nominal and no-load voltage levels are identified below with the future value dependent on LRV maximum operating voltage limitations.

- TPS nominal voltage: 670 V_{DC} (Future 710 V_{DC})
- TPS no-load voltage: 710 V_{DC} (Future 750 V_{DC})

TPSS equipment must be designed to be flexible in its ability to increase nominal and no-load DC output voltage to support the future voltage increase requirements. The TPS must be designed to accommodate the full acceleration and half acceleration criteria outlined below.

6.1.5.1 Full Acceleration Design Criteria

Full acceleration scenarios simulate worst-case conditions that could occur during normal operations where two five-car Trains simultaneously accelerate away from the same Platform in opposite directions. With all TPSS in service, the TPS modelling must show that the voltage level supplied to the Trains remains above the system low voltage limit of 480 V_{DC}. These load flow criteria must be evaluated for all Stations.

The Designer must coordinate full acceleration load flow operating conditions with the Engineer. The TPS following operational conditions are based on the existing SD-160 LRV fleet:

- Five minute Mainline headway and 2.5 minute headway for overlapping lines
- Five-car SD-160 Train Consists (reduced AC mode)
- 50 kW auxiliary power (based on duty cycle analysis of LRV)
- LRV in reduced power mode (torque taper point at 20 km/h)
- 82 kN maximum tractive effort
- 1.43 m/s^2 maximum acceleration (full power)
- AW3 loading (13.37 t)

6.1.5.2 Half Acceleration Design Criteria (Reduced Operation)

Half acceleration scenarios simulate the TPS with a Mainline TPSS removed from service. With a TPSSTPSS out of service and bypassed, two adjacent TPSS feed the affected OCS section. In the affected section Trains operate at half acceleration; outside the affected area Trains operate normally at full acceleration.

To simulate maximum TP loading under these conditions, Trains traveling in both directions are modelled as simultaneously stopped and started at the midpoint of an affected section. This test is performed to confirm that the TPS voltage measured at the pantograph for each Train is maintained above the system low voltage limit of 480 V_{DC}. A half acceleration analysis must be repeated for each new TPSS and the immediately adjacent TPSS on the existing system being extended or altered. For Terminus TPSS, a half acceleration analysis must be performed with a single Train accelerating from the Terminus Station. The voltage to the Train must remain above the system low voltage limit of 480 V_{DC}.

The Designer must coordinate half acceleration load flow operating conditions with the Engineer. The reduced TPS operating conditions shown below are based on the existing SD-160 LRV fleet.

- 41 kN maximum tractive effort (half tractive effort).
- 0.715 m/s^2 maximum acceleration (half acceleration).

All other vehicle parameters are the same as the full acceleration criteria.

6.1.6 Specific Engineering Studies

Specific studies which may be required as part of the Design include:

- Behaviour of conductors, including conductivity, ampacity, tensile strength, and thermal effects
- Corrosion and Stray Current analysis and mitigation, refer to Chapter 13, Corrosion and Stray Current

- Dynamic vehicle clearance analysis for the OCS design, coordinated with the Design Vehicle Dynamic Envelope (DVDE), as provided in Chapter 3, Clearances and Right-of-Way
- Behaviour of supporting structures under static and dynamic loading
- Pantograph security analysis
- Analysis of electrical interference with electronic devices
- Analysis of electrical interference with health & safety standards
- Impact of TPSS noise

The need for any of these studies must be determined jointly with the Engineer and may involve coordinating with other elements of the Design.

6.2 TPSS

6.2.1 General Design Principles

The following general principles must be applied to Design of new, or renewal of existing TPSS:

- Maintain a consistent design approach
- Coordinate equipment service life expectancies with the LRT System service life requirements
- Consider "lessons learned" from design of previous TPSS
- Standardize all major equipment as much as practicable
- Coordinate new facility design with existing systems
- Confirm that operational and load requirements are accommodated in terms of capacity, reliability, and maintainability of the system
- Maintain consistent TP protection and control systems operational performance, and philosophy with existing TPSS

6.2.2 Studies and Calculations

The following AC and DC studies and calculations must be applied to the design of new TPSS. These studies must be developed through detailed design and are required to establish the overall TPS Design. The methods used and results obtained in these studies must be submitted to the Engineer for review.

- Short circuit and fault analysis
- Protection and coordination study
- Arc flash and incident energy study
- Step, touch, and ground potential rise analysis
- Lightning/surge analysis
- Heat rejection analysis

At a minimum, the following studies are required for major equipment renewal projects for existing TPSS:

- Short circuit and fault analysis
- Protection and coordination study
- Arc flash and incident energy study

6.2.2.1 Short Circuit and Fault Analysis

A short circuit and fault analysis must be performed to confirm that all TP equipment and cables are rated for the maximum available fault current on the system as coordinated with the utility provider. This analysis must be performed using a recognized software package accepted by the Engineer.

6.2.2.2 Protection and Coordination Study

A protection and coordination study must be performed in coordination with the utility provider to confirm that all TP equipment and cables are protected, and all protection elements are coordinated to operate effectively during ground fault, phase fault, and/or DC current fault conditions.

6.2.2.3 Arc Flash and Incident Energy Study

An arc flash study must be performed to identify the specific arc flash hazards for the TP electrical equipment, including a calculation of the incident (arc flash) energy. The Designer must perform the study with the intent of minimizing arc flash energy levels without creating nuisance tripping during ground fault and/or phase fault conditions. In cases where incident energy levels are high, mitigation techniques must be applied to effectively reduce energy levels. Refer to the City of Edmonton Facility Design & Construction Consultant Manual – Volume 2 Appendix E for details.

6.2.2.4 Step, Touch, and Ground Potential Rise Analysis

A step, touch, and ground potential rise analysis must be performed to establish the ground grid design in and around a stand-alone TPSS building or Utility Complex (UC). The analyzed grid must be designed to achieve simulated safe step and touch voltages and must consider:

- Site conditions, including soil resistivity, moisture, and temperature
- Power system parameters, including maximum fault current conditions and fault clearing duration
- Maximum allowable ground resistance
- TPSS or UC proximity to utility provider system equipment and the LRT ROW
- Maximum allowable ground potential rise as per the CEC.
- Interface with the TPSS or UC structural design for potential bonding of structure reinforcement.

The analysis must follow the IEEE Std 80, Guide for Safety in AC TPSS Grounding [43].

6.2.2.5 Lightning/Surge Analysis

A lightning/surge analysis must be performed to confirm the placement of lightning and surge protection devices along the TPS from the medium voltage supply through to the positive DC feeder supply and negative feeder return to the TPSS. The analysis must also confirm ratings of the lighting and surge protection devices to withstand maximum local lightning and surge values.

6.2.2.6 Heat Rejection Analysis

A heat rejection analysis must be performed for the specific traction power equipment and cabinets to confirm that adequate heating and cooling are provided to meet the required operating temperatures of the equipment. Refer to Chapter 12, Mechanical for specific requirements.

6.2.3 TPSS Facilities

6.2.3.1 TPSS Types

The LRT System uses three types of TPSS facilities: within a UC, as a stand-alone building, and integrated within a Station.

Utility Complex

A UC is a single building that houses the TPSS, Signals, communications, electrical distribution, and other services within dedicated rooms. At these UC, the TPSS must power a dry type station service transformer for standby power to the building and LRT ROW electrical systems, refer to Chapter 11, Electrical Systems for additional information.

Stand-Alone

Where other full system rooms are not required, a stand-alone TPSS may be located in a separate structure between or near Stations. Communications and other systems required to service the TPSS must be located in a separated room with a dedicated exterior access door. Where a temporary or short-term TPSS is required, a portable (pre-fabricated) stand-alone TPSS may be considered for use..

Integrated

Where appropriate, a TPSS may be integrated into a Station facility.

6.2.3.2 Building Design

The TPSS must be designed to house the following TP equipment and essential support systems:

- Dual utility feeds (Line 1 and Line 2) with an auto transfer system
- Utility metering equipment
- AC switchgear
- A rectifier transformer
- A rectifier and interphase transformer
- 1000 V_{DC} switchgear
- Line and bypass switches
- A negative disconnect switch
- A rail ground switch
- 125 V_{DC} battery bank, chargers, and DC distribution panel
- 125 V_{DC} control power system
- A single or two separate cabinets that houses each of the SCADA and PLC system, including:
    - SCADA Equipment
    - A remote terminal unit
    - Network equipment
    - A fibre patch panel
    - PLC Equipment
    - Local PLC input/output, power, and communication modules
    - Local Human Machine Interface (HMI) annunciation panel
- A TPSS grounding system including adequate ground grids
- Fire alarm and intrusion detection systems
- Heating and ventilation systems (if stand-alone or portable)
- Station service equipment (if stand-alone or portable)
- A first aid kit
- An eye wash station

In some instances, TPSS may be located in a critical LRT operating area. These areas may include:

- A Mainline section in which Train frequency is increased
- Connection points where two LRT segments merge to a single line
- At Operations and Maintenance Facilities (OMF)

In these instances, fully redundant dual transformer and rectifier units should be provided in the TPSS. If dual transformers are provided, either unit should be capable of carrying the entire load of the TPSS. The capacity requirement of each transformer must be coordinated with the Engineer.

6.2.3.3 Building Design and Services

Design guidelines for TPSS rooms and stand-alone buildings are provided in Chapter 10, Stations and Ancillary Facilities.

6.2.3.4 Medium Voltage Utility Service

Each TPSS must be supplied by two MV feeders originating from different utility TPSS, or at a minimum, from different supply buses in the same TPSS. These two feeders must be designated as Line 1 and Line 2, and must be terminated at AC switchgear in the TPSS. The TPSS MV AC switchgear provides switching and control for the Line 1-Line 2 scheme and must be equipped with Line 1 and Line 2 breakers accompanied by an auto transfer system.

Auto transfer system operation must be controllable in a manner that allows the Operator to designate Line 1 or Line 2 as the preferred main feed. A third setting must allow the auto transfer to be placed into manual, thereby turning off the auto transfer system. This method allows flexibility in the event a utility provider alters the incoming feeds and their main or standby designation. In the instance that Line 1 or Line 2 supply is lost, the system must automatically transfer over to alternate supply if the auto transfer is designated accordingly. The system must not transfer back to designated main supply from a standby supply.

At some locations, an alternate feed to a TPSS or UC may not be available or may be an unacceptable project cost. At these locations, the TPSS designs must include provisions for an alternate feed should one become available in the future. These provisions include space for a standby breaker and associated metering cell as well as underground ducts for a standby feed.

6.2.3.5 Low Voltage Station Service

In addition to the two MV feeds from the utility service provider, a separate utility-owned 600 V station service transformer power feed must be made available to the TPSS or UC. As part of a UC, the TPSS MV switchgear will power a standby 600 V station service transformer to provide the building with lighting, building security, systems power and heating in the case of a power outage on the main supply. For stand-alone or portable TPSS, a stepdown transformer designed into the MV switchgear must provide standby station service power to the TPSS building.

6.2.3.6 TPSS Control Power

Each TPSS must be equipped with an auxiliary power supply system to provide nominal 125 V_{DC} power to all switchgear protection and control systems. The auxiliary supply must include a battery bank, battery charger, and DC distribution panel. The battery bank provides power to the control circuits during a total power failure.

Battery banks must be located in the TPSS and be sized to provide backup control power for a minimum of eight hours. Battery technology with low hydrogen emissions must be used to eliminate the need for a specialized room or cabinet and additional room or building ventilation.

6.2.3.7 Raceways

General design requirements for TPSS raceways are outlined below:

- An Electrical Metallic Tubing (EMT) conduit must be used for all indoor low voltage applications

- A galvanized rigid steel conduit must be used for all outdoor above-grade services and ducts attached to the face of tunnel walls or MV installations within buildings
- For DC TP cables, Reinforced Thermosetting Resin Conduits (RTRC) must be used for all outdoor above-ground services and ducts attached to tunnel walls
- PVC conduit must be used for underground and concrete encased installations. Refer to Chapter 11, Electrical Systems
- Rigid schedule 40 PVC conduit may be used for added mechanical protection in direct burial applications, exposed exterior TP conduit runs, or where required due to installation constraints
- Rigid steel must not be used to sleeve single AC conductor cables
- Where practicable, conduit penetrations through structures should be grouped
- The minimum size of conduit installations must be 25 mm
- All conduit installations must provide a minimum of 25% spare capacity for future wire/cable runs
- Dedicated feeder ducts must be provided for each individual positive feeder between the TPSS and the OCS line
- Dedicated feeder ducts must be provided for negative feeders between the TPSS and rail
- For each positive and negative feeder, 25% redundant capacity must be provided in separate equal size conduits, with an adequately rated nylon pulling string provided in each

6.2.3.8 Grounding

Effective grounding of the TPS is required for personnel safety, equipment protection, prevention of static charges, fault protection, neutral grounding, operation and coordination of protective relays, and instrumentation and communication equipment interference protection. All equipment and enclosures within the TPSS must be bonded to the main ground grid to eliminate touch potential.

General design requirements for the UC or TPSS grounding are outlined below:

- Ground grid must extend to the exterior permitting the bonding of all conductive and non-current carrying objects within 2 m of the TPSS
- All grounding conductors must be sized and installed in accordance with the CEC [42] and the materials must be suitable for the environment they will be installed in
- The maximum TPSS ground resistance must be 1 Ω
- The DC switchgear, rectifier enclosures and positive feeder line, and bypass switches must be connected to the main ground grid through their dedicated frame fault protection relay
- A DC surge protection system triad ground grid must be provided separate from the main grounding grid
- The main ground grid must be interfaced with Lighting Protection Systems at UCs
- The main ground grid must be interfaced with ROW grounding where a UC or TPSS is placed in close proximity to the ROW
- The main ground grid must be interfaced with utility provider grounding grid where the utility provider equipment is placed in close proximity to a UC building.
- The grounding requirements for the utility provider equipment must be clearly identified as utility providers may have specific guidelines that differ from the UC ground grid requirements

6.2.4 TPSS Equipment

The TPSS equipment arrangement for critical operational areas includes fully redundant dual AC feeds and transformer/rectifier pairs. These dual MV AC utility feeds are connected to a Line 1-Line 2 breaker scheme with an automatic transfer system. Each TPSS is normally fed through either of the two AC feeder breakers and connected to rectifier breakers which supply two TP transformer-rectifier units. Each rectifier feeds the DC switchgear positive bus through a dedicated DC main breaker which distributes positive power to the OCS through four high-speed feeder circuit breakers. The rectifier negative circuit is connected to a negative cabinet, which houses a negative disconnect switch connected to the rail completing the return path for the TPS.

For non-critical locations, dual AC utility supplies should be implemented with an automatic transfer scheme. Single transformer-rectifier units, with a minimum rating of 2.0 MVA should be installed.

The TPSS must be designed to support half acceleration operation with an adjacent TPSS out of service.

Where practicable, the DC positive circuit feeder and Tie Switches should be housed in a single switch lineup mounted within a TPSSTPSS or against an exterior TPSS wall. A negative transition cabinet within the lineup may be used to provide a negative return feeder transition between the TPSS and rail. Appendix 6A Figure 6.1A and 6.1B show typical TPSS equipment layouts.

6.2.4.1 Operating Conditions

TPSS equipment must be located indoors in a room classified as non-hazardous. The operating temperature range for equipment is 0° C to +40° C and average altitude is provided in Chapter 1, General. In manned facilities, equipment design must account for a clean agent fire suppression system.

6.2.4.2 Medium Voltage AC Switchgear

MV AC switchgear includes equipment required for monitoring and controlling Line 1 and Line 2 incoming AC feeder breakers, and AC rectifier breakers for the primary power supply for TPS and the standby Station service transformer. Switchgear contains utility metering equipment, utility metering disconnect switches, AC breakers, AC fused disconnect switches, auxiliary power, and protective equipment. Each cell must have its own dedicated control power from the DC distribution panel. Switchgear must be of metal-clad design as per IEEE C37 20.2 [44] and the design must incorporate closed door racking for all breakers.

Where dual AC feeders are available, the AC switchgear will use a Line 1-Line 2 scheme with an auto transfer system. Adequately sized lightning arrestors must be provided in each incoming line cubicle. In Edmonton the local utility has 15 kV and 25 kV distribution depending on location within the city.

Standard rating for the AC switchgear is:

- Rated nominal voltage: 14.2 kV or 25 kV
- Rated maximum voltage: 15 kV or 25 kV
- Minimum main bus continuous current: 600A or 1200 A
- Frequency: 60 Hz
- Basic Impulse Level: 110 kV
- Fault Interrupting Capacity: 750 MVA to be confirmed with fault levels available from the local utility provider
- Arc resistant accessibility type 2C

AC switchgear must meet the utility provider's requirements, such as the EPCOR Customer Connection Guide [45]. Utility metering cells are required for each incoming service.

Metering transformers must be installed on the load side of circuit breakers and must be capable of being isolated electrically from both supply and load. On services with the possibility of an alternate source or an on-site generator, gang operated isolating switches with contact operation verifiable by direct visible means must be installed. These isolating switches must be placed after the cabinet for current transformers and before transformers or other equipment.

Provision must be made for installation of potential transformers in a drawer type cabinet with high and low potential opening devices. These drawers must fully extend for the cabinet depth. The cabinet must support three potential transformers and must be at floor level. A hinged door with provision for sealing must be installed to provide access to the potential transformers. Pin type contacts are not acceptable.

MV breakers must be floor racked allowing for easy removal during maintenance. Stacked breakers may be considered in existing buildings and structures where space is limited.

In general, the AC switchgear design and procurement must be coordinated with the local utility provider, ensuring adequate review of switchgear design including the metering cells, specific potential and current transformer inclusion, and overall protection and control design.

6.2.4.3 DC Switchgear

DC switchgear functions as the control and protective equipment for DC power distribution to LRVs. DC switchgear includes one or more DC main breakers fed from rectifiers, and four or more high speed, single pole circuit breakers for positive feeders to the OCS. DC switchgear for critical and OMF TPSS may contain additional main and feeder breakers. Each cell must have its own dedicated control power from the DC distribution panel. In general, each feeder breaker feeds a specific section of track in parallel with its adjacent TPSS feeder. This provides additional redundancy in the OCS network, allowing Trains to continue to operate on a single feeder if a single TPSS is out of service.

DC switchgear must be isolated from ground either by a fiberglass reinforced thermoset polyester sheet, or a non-conducting epoxy floor. A special grounded and hot structure protection scheme must be included for the switchgear as it will be isolated from ground. Protective relaying for each DC feeder breaker and incoming main breakers must be contained in the DC switchgear. The switchgear must be metal enclosed and must be built in accordance with IEEE 37.20.1 [44].

Standard ratings for the LRT System DC switchgear are:

- Nominal voltage: 750 V_{DC}
- Maximum voltage: 1000 V_{DC}
- 60 Hz withstand voltage: 3700 V_{AC} (RMS)
- DC withstand voltage: 5200 V_{DC}
- Continuous current rating: 6000 A_{DC}
- Main breaker current rating: 6000 A_{DC}
- Feeder breaker current rating: 4000 A_{DC}
- Peak closing and latching current: 200 kA_{DC}
- Rated short circuit current: 150 kA_{DC}

These ratings must be verified by the Designer and confirmed with fault levels available from the utility provider, and propagation of fault current through a short circuit and fault analysis.

6.2.4.4 Traction Power Rectifier and Interphase Transformer

Each rectifier, interphase transformer, and rectifier transformer must be sized and specified as a coordinated set. The rectifiers must be naturally ventilated TP rectifiers with silicon disc-type diodes. They are considered 12-pulse rectifiers with two three-phase bridges connected in an IEEE C57.18.10 Circuit 31 configuration [46]. Standard ratings for the LRT System rectifiers are:

- Output: 2000 kW, 660 V_{DC}, 3030 A_{DC}, continuous
- Overload rating of 150% for 2 hours

- Overload rating of 300% for 1 minute
- Full wave diode bridges providing 12-pulse rectification
- N-1 diode design rating
- Natural convection cooling type ANN

Rectifiers must be isolated from ground either by a fiberglass reinforced thermoset polyester sheet or a non-conducting epoxy floor. In designs that combine a rectifier with DC switchgear, ground and hot structure protection may be combined. For stand-alone rectifiers, a dedicated grounded and hot structure protection scheme must be provided for the rectifier as it will be isolated from ground.

Rectifiers must be designed to meet heavy traction service as per IEEE 1653.1 [47], specification for heavy traction service stating that after 100% full load temperatures are reached the rectifier must withstand, without damage, the following additional overloads:

- 150% load for two hours
- 300% load for one minute at the end of the two hours

Rectifiers must have a base load resistor to limit voltage output during periods of no load. Rectifier design must incorporate complete assemblies consisting of all rectifier elements, heat sinks, internal buses, fuses, diode failure and over-temperature protection, rectifier over-temperature protection, rectifier surge protection, and all necessary components matched to the TP transformer.

The interphase transformer must be designed to operate as a coordinated set with the rectifier and transformer. The interphase transformer must be designed to balance DC output of the two 3-phase rectifier bridges.

Standard ratings for the LRT System interphase transformers are:

- Natural convection cooling type ANN
- Insulation class 220
- Designed to meet heavy traction service as per IEEE 1653.1 [47], stating that after 100% full load temperatures are reached the interphase transformer must withstand, without damage, the following additional overloads:
    - 150% load for two hours
    - 300% load for one minute at the end of the two hours

6.2.4.5 Negative Disconnect Switch

Rectifier negative disconnect switches must be manually operated non-load break used to isolate the rectifier from the rail. Switches must be mechanically interlocked with their associated DC main breaker to prevent operation under load conditions. The mechanical interlock must be truck mounted and prevent the associated main DC breaker from being re-inserted into its DC switchgear cubicle. Switches must be rated the same as the rectifier and DC switchgear main bus and include an adequately rated lighting arrestor at the entry of the negative return circuit cables routed from the LRT rails.

6.2.4.6 Rectifier Transformers

The rectifier transformer, rectifier, and interphase transformer must be sized and specified as a coordinated pair. The rectifier transformer pair must be able to accommodate the maximum anticipated load for the system it will be supporting and must be tested at rated load to verify performance of the pair. In addition, the rectifier transformer must meet the following requirements:

- Designed to meet heavy traction service as per IEEE 1653.1 [47], stating that after 100% full load temperatures are reached the transformer must withstand, without damage, the following additional overloads:
  - 150% load for two hours
  - 300% load for one minute at the end of the two hours
- Have a dual winding secondary in a Δ – Y configuration 30% phase displacement to feed the 6-phase – 12 pulse rectifier, as per Circuit 31 of IEEE C57.18.1 [48]
- Be dry-type and self-cooled
- Include temperature monitoring devices with adjustable alarm and trip contacts
- Be designed to accommodate all scenarios for all possible Train Consists as described in the project requirements

Standard ratings for an LRT System rectifier transformer are:

- Nominally rated at 2100 kVA (this rating must be verified prior to commencing final design)
- Type: ANN
- Primary Phases: 3
- Secondary Phases: 6
- Frequency: 60 Hz
- Class 220 insulation (150° C rise above 40° C Ambient)
- Primary Basic Impulse Level (BIL): 110 kV
- Secondary Basic Impulse Level (BIL): 45 kV
- Primary voltage: 14.2 kV or 25 kV Δ
- Secondary voltage: 519 V Δ, 519/300 V Y
- Taps (offload): +2x2.5%, -5x2.5% primary[1]
- Winding material: copper
- Voltage regulation not greater than 6% from 1% load to full load

6.2.4.7 Rail Ground Switch (RGS)

An RGS in each TPSS must provide automatic detection and grounding of the negative bus if rail to ground voltage exceeds an adjustable pre-set level of either polarity. The RGS must:

- Have multiple adjustable protection setpoints for permissible voltage magnitudes and durations, and must include an adjustable voltage setpoint for instantaneous closing of the switch
- Consist of a thyristor solid state switch paralleled with a contactor to provide continuous current support
- Be designed to withstand maximum current (by magnitude and duration) that may occur in a worst-case ground fault
- Be capable of opening automatically once the rail overvoltage event is cleared
- Be equipped with a local HMI for setpoint input, event, and fault indication and logging
- Be capable of communication with the TPSS PLC
- Include an adequately rated surge arrestor at the entry of the negative return circuit cable typically routed from the Negative Disconnect Switch.

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[1] The transformers must include three additional transformer taps in addition to the standard five primary taps to allow the system to be operated at a higher voltage in the future if required. These three additional taps must be added at -7.5%, -10%, and -12.5%.

6.2.4.8 Auxiliary Power Supply System

A 125 V_{DC} auxiliary power system is used for the basic TPSS controls, relaying, PLC, HMI, and SCADA Remote Terminal Unit (RTU) equipment, communication equipment, and alarm functions. The system consists of a storage battery bank, matched battery charger/inverter, and DC distribution panel.

The battery and its circuits must be properly designed, safeguarded and maintained, and the emergency requirements must be carefully estimated to provide adequate battery performance during emergencies or total loss of power for eight hours. Batteries must be of low hydrogen emission design for indoor installation.

A battery charger must be independent of the condition of the battery bank. It must support full DC power output while AC supply is available. Basic requirements for battery bank and charger are:

- Nominal system voltage of 125 V_{DC}
- Minimum stored energy capacity adequate to supply the load demand for eight hours during a total power loss
- Positive and negative ground detection, alarm modes, and temperature compensation
- Float and equalization capability
- Low and high voltage alarms
- Modular individual battery cell design
- Adjustable charger output to accommodate specific battery manufacturer cell voltage requirements
- Charger failure alarm

The sizing of the DC auxiliary power supply must be based on a duty-cycle evaluation of the entire auxiliary system load.

6.2.4.9 Wiring Methods

Wire installations must be designed as per the CEC [42].

Cable in tray should be used for routing cables to improve cable cooling. However, a conduit may be used when it is difficult to support the cable, or when additional mechanical protection is required.

All cables and conductors used must meet CSA C22.2-239 and C22.2 No. 38 requirements. Any other codes and standards applied by the Designer must be approved by the Engineer.

6.2.4.10 Bus Bar and Bus Connectors

Bus bars and connectors must be made of tin-plated copper. Bus bar and connector capacities must be verified by the Designer. Typically bus bar and bus connectors on the LRT System are sized as follows:

- For 1000 V_{DC} switchgear – 6000 A_{DC} continuous
- For MV AC switchgear – 600 or 1200 A continuous

6.2.5 TPSS Status and Control

All TPSS must be equipped with a PLC to provide local and remote control of TPSS equipment. The PLC must communicate with an HMI touchscreen display that provides local active single line display, annunciation, secured control, event and alarm data logging, and download. The PLC system must be designed to integrate and control all switchgear functions, system monitoring and data logging. The PLC, HMI, and RTU functionality should be integrated into a single device with a touch HMI display used as a system peripheral. For instances where the PLC and RTU devices are separate, the PLC must communicate directly with the RTU. The SCADA system must include a network device and fibre patch panel to communicate with the EPCOR Control Centre via the Owner's fibre network.

6.2.5.1 TPSS PLC and Local HMI Annunciation

Each TPSS must be equipped with a local Programmable Logic Controller (PLC) and local annunciation must be provided by the HMI display unit for the following standard functions:

- MV AC breaker status and position
- MV AC breaker protection relay status, alarms and trips
- MV AC Line 1 and Line 2 breaker analog line voltage
- DC breaker status and position
- DC breaker protection relay status, alarms and trips
- DC switchgear main breaker analog amps and bus voltage
- DC switchgear feeder breaker analog amps and OCS line voltage
- Negative disconnect switch status and position
- Negative disconnect switch alarms
- RGS status and position
- Status and all alarm points of 125 V_{DC} auxiliary control power system
- Tx winding temperature, alarm and trip
- Rectifier temperature, alarm and trip
- Rectifier diode failure, alarm and trip
- Rectifier overvoltage
- All individual frame fault trips
- Rail overvoltage, alarm and trip
- AC over/undervoltage
- DC feeder overvoltage
- All DC door open trips
- All transformer door trips
- DC rectifier reverse current trip
- Feeder and Tie Switch status if incorporated in TPSS design
- Emergency trip station status
- All lockout relay alarms and status

6.2.5.2 SCADA RTU

The RTU must be equipped with dual output, typically over ethernet. One output may be used by the Operator only to monitor the required TPSS status points through their own dedicated interface. The second output is provided to the EPCOR Control Centre for status and control of the various TPSS devices. Both RTU outputs must be designed to connect to a dedicated network switch that completes the interface with the Owner's fibre communications backbone. The EPCOR Control Centre monitors and controls, at a minimum, the following at each TPSS:

- MV switchgear status and remote control
- MV switchgear analog line voltage and phase current
- DC switchgear status and remote control
- DC main breaker analog amps and bus voltage
- Negative disconnect switch status
- Transformer status
- Rectifier status
- RGS status

- DC feeder and Tie Switch status if switch bank is included in the TPSS design
- 125 V_{DC} auxiliary power system status
- Emergency trip station status
- SCADA failure
- PLC failure
- Lockout relay status

All TPSS device status, control, and alarm indication signals should be routed to the TPSS HMI and RTU as a consistent list. This allows the EPCOR Control Centre to choose specific monitoring and control points and provide future expansion of their points list if deemed necessary for improved maintenance and monitoring of the system. A proposed full TPSS input/output list must be developed by the Designer and be reviewed by the Engineer, Operator, and control operator. The list must define control and status points, method of communication if not hardwired, and if local and remote status or control is required.

6.2.5.3 TPSS/UC Building Systems

In addition to the items listed above, the following TPSS status information must be communicated to the RTU:

- Fire alarm
- TPSS intrusion alarm
- TPSS inside temperature from the Building Management System (BMS)
- Vault high water level

Refer to Chapter 12, Mechanical for full BMS system requirements and Chapter 8, Communications for information on coordinating the above listed points with systems monitoring.

Fire and Smoke Detection System

All TPSS must be equipped with smoke detectors and fire alarm systems. Ventilation and heating ducts must also include smoke detectors installed with automatic shut-off capabilities.

Refer to Chapter 11, Electrical for full fire alarm and detection requirements.

Sprinklers/Fire Suppression System

Sprinkler systems are prohibited in TPSS. Where fire suppression is required, such as in TPSS installed in maintenance facilities or integrated in Stations, a clean agent fire suppression system must be used.

Refer to Chapter 12, Mechanical for full fire protection system requirements.

Occupancy and Intrusion Detection

Stand-alone TPSS must be equipped with a full intrusion detection alarm system, with remote monitoring capabilities. Integrated TPSS must have remote monitoring capabilities installed on all entrance doors. Both types of TPSS must have card reader access on all main doors.

Refer to Chapter 8, Communications for card access system requirements.

Heating, Ventilation, and Cooling

Adequate Heating, Ventilation, and Air Conditioning (HVAC) must be provided at each TPSS to maintain an indoor temperature range provided in Chapter 12, Mechanical. The HVAC system Design must be coordinated with heat rejection calculations for the TPSS electrical equipment. Specific ventilation requirements must be coordinated with the design of the auxiliary power supply system, specifically the battery bank.

Refer to Chapter 12, Mechanical for full HVAC requirements.

6.2.6 Protection Systems and Devices

TPSS design must incorporate electrical system protective devices to minimize damage to equipment and avoid hazards to personnel from overloads, faults, and other abnormal conditions. All AC and DC feeder management relays must be capable of event recording, waveform capture, and time synchronization. All other protection devices that do not have these features must be capable of communicating with the TPSS PLC to record event history.

6.2.6.1 AC Switchgear

The following relaying protections must be included for AC breakers:

- Phase inverse time and instantaneous overcurrent protection
- Ground inverse time and instantaneous overcurrent protection
- AC undervoltage/overvoltage protection (AC feeder breakers only)
- Loss of 125 V_{DC} control voltage
- Transformer/Rectifier thermal overload relay (AC rectifier breakers only)
- AC feeder lock-out relay
- AC transformer and rectifier lock-out relay
- Automatic transfer (AC feeder breakers only)
- AC breaker fail
- Loss of communications
- Trip coil monitor for trip coil failure detection

6.2.6.2 DC Switchgear

The following protection elements must be included for each DC feeder breaker:

- Direct acting high speed DC instantaneous overcurrent trip device
- Loss of 125 V_{DC} control voltage
- DC instantaneous overcurrent (forward and reverse)
- DC feeder time overcurrent (forward and reverse)
- DC rate-of-rise overcurrent
- DC Δ I overcurrent
- DC breaker fail
- Load measure and reclose
- Transfer trip
- DC overvoltage
- Shunt failure
- Voltage and current transducer failures
- Loss of communications

In addition, the DC switchgear must include the following:

- DC main breaker reverse current protection
- DC main breaker direct acting DC instantaneous overcurrent trip device
- DC main breaker fail

- Frame fault protection (grounded frame and hot structure)
- Rail overvoltage relay alarm (as back-up to RGS protection)
- DC lock-out relay
- PLC failure
- Shunt failure
- Voltage and current transducer failures
- Loss of communications

6.2.6.3 Rectifier Transformer

The following protection elements must be included for each rectifier transformer:

- Transformer door open trip
- Transformer temperature alarm and trip

6.2.6.4 Rectifier

The following protection elements must be included for each rectifier:

- Rectifier door open trip
- Frame fault protection (grounded frame and hot structure for stand-alone units only)
- Rectifier temperature alarm and trip
- DC rectifier transformer lock-out relay
- Rectifier diode failure alarm and trip
- Rectifier AC and DC positive and negative fuse failure protection

6.2.6.5 Rail Ground Supply

The following protection elements must be included for the RGS:

- Rail to ground overvoltage alarm
- Rail to ground overvoltage time delayed trip (multiple setpoints)
- Rail to ground overvoltage instantaneous trip

6.2.6.6 Auxiliary Power Supply

The following protection elements must be included for the auxiliary power supply system:

- Battery charger failure alarm
- AC supply failure alarm
- Battery voltage high alarm
- Battery voltage low alarm
- Positive and negative ground fault alarms
- Battery high temperature alarm and trip

6.2.7 Protection Relay Descriptions

6.2.7.1 Automatic Rail Overvoltage Protection

The rail to ground potential must be monitored to protect the public and ETS personnel against unsafe rail to ground voltages. An RGS in the TPSS must provide automatic detection and grounding of the negative bus if rail to ground voltage exceeds adjustable pre-set levels of either polarity. The RGS must be equipped with multiple time delayed voltage protection setpoints and a single instantaneous voltage protection setpoint. The range of adjustment must provide safe touch potential standard limits and durations.

The RGS must consist of a fast-acting thyristor solid state switch paralleled with a contactor to provide continuous current support, must be designed to withstand the maximum current (by magnitude and duration) that may occur in a worst-case ground fault, must be capable of opening automatically once the rail overvoltage event is cleared, and must communicate with the TPSS PLC.

6.2.7.2 Line Test and Circuit Reclosing (DC Feeder Breaker)

Each DC feeder breaker Feeder Management Relay (FMR) must be equipped with automatic line test and circuit reclosing capability to allow a tripped feeder breaker to automatically test and reclose in the event of a momentary fault on the OCS. The reclosing feature must be adjustable in the number of tests and the delay time between tests. The line test must apply a DC bus voltage between the OCS and negative rails through a resistance bridge to limit the current during the test. If the test is successful, the FMR must re-close the associated breaker returning power to the OCS. If the test fails after a predetermined number of tests, the re-closing relay must lock out. The lockout can be reset by sending an open signal to the breaker remotely or locally. Additionally, this protection feature must include a pre-condition time that locks out the breaker if a subsequent fault occurs during a pre-set period following a successful reclose. The protection scheme must prevent the line test resistors from exceeding their capacity through repetitive execution of the full line test sequence.

6.2.7.3 Reverse Current Protection (DC Main Breaker)

DC main breakers must be equipped with adjustable instantaneous reverse current protection.

6.2.7.4 Instantaneous Overcurrent Protection (DC Feeder Breaker)

Each DC feeder breaker must be equipped with instantaneous forward and reverse overcurrent protection. Protection devices with a time delay must have the ability to adjust their time delay duration to a millisecond level to mimic an instantaneous trip.

6.2.7.5 Current Step/Jump Protection (DC Feeder Breaker)

Each DC feeder breaker must be equipped with a current step protection element that allows the FMR to detect and clear close proximity faults characterized by current of high magnitude or high rate-of-rise. This protection must be adjustable in threshold and time delay to allow flexibility in limiting the amplitude of a fault.

6.2.7.6 Current Rate-of-Rise Protection (DC Feeder Breaker)

The DC FMR must be equipped with current rate-of-rise monitoring to detect distant faults with peak current below the FMR overcurrent settings. The FMR must be adjustable with respect to current rate-of-rise (d_i/d_t) and time to allow the FMR to distinguish between normal loads and long-distance short circuits. The FMR must be capable of detecting a long-distance fault when an adjacent TPSS is removed from service.

6.2.7.7 Definite Time Overcurrent Protection (DC Feeder Breaker)

The DC FMR must be equipped with definite time overcurrent protection to monitor feeder circuit overloads that slightly exceed the continuous current rating of the TP distribution cables and wires. The current threshold and time delay must be adjustable to allow the FMR to distinguish between fault conditions and normal Train loading conditions. This protection feature must be available for both forward and reverse current directions.

6.2.7.8 Over Voltage and Under Voltage Protection (DC Main and Feeder Breakers)

The DC main breakers must be equipped with both over and under voltage protection to protect operation of the upstream rectifier. Both voltage thresholds and time delays must be adjustable. The DC feeder breakers must be equipped with over voltage protection with the same voltage threshold and time delay adjustment flexibility to adequately protect downstream equipment and LRVs against insulation damage due to voltages exceeding equipment ratings.

6.2.7.9 DC Breaker Fail (DC Main and Feeder Breakers)

The DC main and feeder breakers must be equipped with breaker fail protection that detects when current continues to conduct through an open breaker. This protection must initiate a lock-out of DC switchgear and upstream transformer and rectifier pair to adequately isolate the fault. In TPSS where transfer trip protection is included, the breaker fail must also initiate a transfer trip to all adjacent DC feeder breakers that may potentially supply fault current to a faulted breaker.

6.2.7.10 DC Switchgear and Rectifier Frame Fault Protection

Through a single point to ground, the frame fault protection monitors DC switchgear and rectifier for unintentional grounds or electrical shorts to the frame. The DC switchgear and rectifier must be isolated from ground using insulating materials. In the event of DC faults to the frame, this protective relay must detect the fault, sending a trip signal to the TPSS PLC. The PLC must initiate a mass trip clearing all the MV AC rectifier breakers and DC breakers in the TPSS, sending a transfer trip to adjacent TPSS. In the event a rectifier main bus faults to frame, this protective relay must detect the fault, sending a trip signal to the TPSS PLC. The PLC must initiate an AC rectifier lock-out, clearing the corresponding upstream AC rectifier and downstream DC main breaker. This will effectively isolate the rectifier and transformer from the supply. In the event of an unintentional ground, the protective relay must send an alarm to the TPSS PLC.

6.2.7.11 TPSS Surge Protection

Each TPSS must be equipped with a series of AC and DC surge protection devices designed to divert overvoltage events to earth to protect cables and equipment inside the TPSS. Surge protection devices must be adequately rated for maximum voltage and fault current possible. For each MV and low voltage AC service entering the TPSS, a surge protection device that meets the local utility provider’s requirements must be installed on the line side of TPSS equipment. For each DC positive and negative circuit entering the TPSS, a surge protection device must be installed. Location of the surge protection devices must be determined by the Designer and accepted by the Engineer. In areas where the alignment passes under an electrical utility transmission line, surge protection devices must be designed to withstand the maximum voltage and fault current from the utility.

6.2.7.12 Rectifier Fuse/Surge Protection

Each rectifier unit must have current limiting fuses in series with a surge suppressor to protect their diodes. A device must be installed to detect fuse failure and subsequently alarm both the TPSS PLC and SCADA system to the EPCOR Control Center. In addition, each rectifier must include AC input surge protection and DC output positive and negative surge suppression.

6.2.7.13 Rectifier Base Load Resistor

A base load resistor must be incorporated into the rectifier design to prevent output voltage from becoming excessive during periods of no load.

6.2.7.14 Rectifier Thermal Protection

Rectifiers must use a two-stage thermal alarm and trip protection scheme for each diode in both 3-phase bridges with sensors incorporated into the diode heat sinks. Rectifier protection devices should be capable of providing alarm and trip status points over the TPSS communications network to the PLC.

6.2.7.15 Transformer Thermal Protection

The rectifier transformers must include an adjustable two-stage thermal alarm and trip protection. The protection device should use thermocouples for temperature measurement installed in each of the transformer's three coils. The transformer protection devices should be capable of providing current temperature, alarm, and trip status points over the TPSS communications network to the PLC.

6.2.7.16 Transfer Trip Protection

A protection trip of any DC feeder breaker must initiate a transfer trip to the breaker feeding the same OCS section in an adjacent TPSS. When a TPSS is removed from service, the transfer trip protection must bypass the TPSS out of service and communicate between the two adjacent TPSS supporting the OCS section with the TPSS out of service.

6.2.7.17 Emergency Trip Stations

Emergency trip stations are used within a TPSS or OMF to allow maintenance personnel the ability to quickly de-energize an entire TPSS or maintenance zone in an emergency. As such, emergency push buttons must be hardwired to the associated mass trip lock-out relay or building zones and not executed via a local PLC.

6.2.7.18 Mainline

Emergency trip stations must be provided in all TPSS. Activating the emergency trip station must trip both the MV AC breakers and DC feeder breakers. Operating the trip station must also send a transfer trip signal to adjacent TPSS, de-energizing the OCS on both sides of the TPSS. Emergency trip stations must be located near each man door in an area that is easily accessible within each TPSS, and clearly identified as an emergency trip station. The trip station must be designed with a guarded pushbutton to prevent accidental operation.

6.2.7.19 Operations and Maintenance Facilities

Emergency trip stations must also be provided at all OMF. Activating the emergency trip station should trip the associated DC contactor, de-energizing the section of OCS in the zone of the trip station. In areas where multiple zones are provided in a single maintenance building, activation of an emergency trip station must de-energize all contactors and associated OCS in that building. This allows maintenance personnel to react quickly to emergencies regardless of their location in the building. Trip stations must be installed inside OMF buildings, as well as in the yard. Emergency trip stations must be easily accessible and clearly identified. The trip station must be designed with a guarded pushbutton to prevent accidental operation.

6.2.8 Power Distribution System

The PDS consists of all feeder (positive and negative) conductors, switches, duct banks, and associated hardware that feeds DC power from the TPSS to the OCS with a return path through the rails.

6.2.9 Operating Conditions

PDS equipment located inside facilities must be designed to operate from 0° C to +40° C. Where a clean agent fire suppression system is required, the Design must consider equipment operation in that environment. Operating conditions in tunnels must be determined by the Designer in consultation with the Engineer. For open LRT Trackways refer to Chapter 1, General for environmental conditions.

6.2.10 Positive Feeder Arrangement (Mainline)

For ease of switching during maintenance, connections of the OCS to TPSS DC breakers have been standardized. For Mainline TPSS, positive feeder #1 of one TPSS supplies power to the same OCS section as feeder #3 of an adjacent TPSS. Similarly, feeder #2 of one TPSS supplies power to the same

OCS section as feeder #4 of an adjacent TPSS. This arrangement is maintained as TPSS are added to the system. For TPSS where two lines join, the numbering system may be unique.

6.2.11 DC Feeder Cables

The DC positive feeder, negative return, and parallel feeder cables must meet minimum criteria for the applications listed below.

6.2.11.1 Open Line Applications

The DC feeder cable conductor size must be a minimum of 500 kcmil stranded copper with ampacity as per the system's Design. The cable must have a free stripping flexible jacket to provide mechanical protection, as well as insulation to a minimum 2 kV_{AC}/2.5 kV_{DC}.

6.2.11.2 Tunnel Applications

Additional feeder cables may be required in tunnel sections to provide improved electrical support to the OCS. NFPA 130 [17] identifies enclosed Stations and Trackways as having special cable requirements. Cables used in these situations must meet the following minimum criteria.

The minimum conductor size must be 500 kcmil stranded copper with ampacity as per the Design. Where cable theft is a concern, the minimum conductor size must be 750 kcmil stranded aluminum also rated for the Design ampacity. The cable must include a free stripping flexible jacket to provide mechanical protection, as well as insulation to a minimum 2 kV_{AC}/2.5 kV_{DC}. Cable materials must comply with NFPA130 [17] requirements for fire resistance and low smoke.

6.2.12 Rail Bonds/Cross Bonds

As the rail is the return path for TP current, rail Bonds are required at all Signal equipment locations and insulated and mechanical joints that require isolation of adjacent track sections. This includes rail bonding required for special trackwork installations, such as track crossovers and restraining rail installations. Cross Bonding between rail and track is required at TPSS locations and at midway points between TPSS. Bonding promotes current sharing between adjacent tracks and each running rail.

The quantity, size, connection requirements, and location of rail and Cross Bonds must be determined by the Designer in coordination with the design of the Signal System and the track. Rail and Cross Bonds must meet the minimum criteria for the applications listed below.

6.2.12.1 Open Line Applications

For open line applications, conductor size must be a minimum of 750 kcmil stranded aluminum with free stripping jacketing and ampacity as per the Design. The insulation must be a minimum 2 kV_{AC}/2.5 kV_{DC} XLPE.

6.2.12.2 Tunnel Applications

NFPA 130 [17] identifies enclosed Stations and Trackways as having special cable requirements. Cables must have a minimum conductor size of 500 kcmil stranded copper with ampacity as per the Design; it must have free stripping jacketing and insulation to a minimum 2 kV_{AC}/2.5 kV_{DC}. Cables must meet NFPA 130 [17] requirements for fire resistance and low smoke.

The ampacity requirements of the TPS Design governs ratings of specific Signal components, for example impedance Bonds. Coordination with Chapter 7, Signals is required for TP and Signal System integration.

6.2.13 Medium Voltage AC Power Cables

Medium Voltage (MV) AC power cables must be shielded cable rated for the utility provider's supplied voltage to the TPSS. If MV cable is run in trays, it must be armoured cable. If single conductors are run, all three phases must be installed in the same rigid steel conduit. MV cable must be a minimum size of 1/0 American Wire Gauge (AWG) and must be sized to accommodate heavy traction rating specified in IEEE 1653.1 [47]. Appropriate heat shrink or cold shrink stress cones must be used at cable ends.

6.2.14 Electrical Switches

For new Mainline TPSS, positive and negative non-load break disconnect switches must be located in fibreglass cabinets inside the TPSS. This includes the Tie Switches used to bypass the TPSS DC feeders. The DC feeder cables make their first point of entry into the TPSS through these disconnect switches, therefore lightning arrestors are required within the cabinets on the catenary side of each of the disconnect switches. These switches are electrically interlocked with the associated feeder breaker to prevent operation under load conditions. If fibreglass cabinets have metallic support structures inside, those supports must be grounded through a common frame fault relay that interfaces with the TPSS protection and control scheme.

For PDS renewal of existing TPSS, upgrades should relocate feeder and Tie Switches from pole mounted locations to enclosures in a centralized location outside the TPSS. Electrical interlocks with upstream feeder breakers are still required along with a frame fault protection relay.

Where additional switching/isolation is required, pole and wall mounted switches may be installed. Any pole or wall mounted electrical switches must be designed with hand operation using a remote mechanical handle accessible from ground level that is adequately bonded and grounded. Key interlocks may be used to prevent operation of switches under load. Any switches mounted inside a building must be housed within an enclosure.

Both feeder and Tie Switches must:

- Be designed to withstand mechanical forces necessary to operate over the entire operating temperature range, Chapter 1, General
- Be DC voltage and current rated
- Have plated copper bus and blades
- Be non-load break, non-fused
- Provide the minimum short circuit and continuous current rating as specified by the Designer.

All electrical switches must be installed with adequate signage indicating their identification number, matching the LRT DC circuit schematics. Proposed switch numbering must be provided to the Operator for review.

6.2.15 DC Contactors and Ground Switches

The OCS in an OMF is further sectionalized beyond the basic feeder and Tie Switch arrangement. Contactors are used to isolate individual or groups of tracks, typically designated as zones, depending upon Operation and Maintenance (O&M) requirements. Design of the OMF maintenance zones and protection of the individual or groups of zones must be coordinated with the Engineer and Operator. They are grouped together and mounted in proximity to the area they are controlling. The DC contactor and ground switch systems must be fed by the critical systems of the facility and include an integrated UPS to mitigate system impacts during maintenance activities requiring a transfer of utility supply power.

Each contactor and ground switch must be housed in an enclosure and must have the following minimum functionality:

- Contactors capable of overcurrent trip protection for faults up to their rated current capacity, and trip blocking, with request to trip upstream DC feeder breaker, for faults above rated current capacity
- Isolation of equipment from TPSS supply through complete removal of upstream fuse disconnects
- A motorized ground switch tied to the OMF main ground network
- Electrical interlock between contactor and ground switch
- Full auxiliary system interface including emergency push buttons, energization warning horns and strobe lights, and catenary indicator lights
- Electrical interlock with gates controlling access to overhead gantries and controls for overhead
- Ability to lock out ground switch in closed position to prevent unwanted re-energization of OCS
- Communication interface with upstream TPSS for status and indication of contactor, ground switches, and zone energization
- PLC protection and control scheme to execute all interlocks and interfaces

Contactors, upstream fuses, ground switches, and any control or PLC system should all be housed in separate cabinets. The contactor must be installed at an elevated location away from operators. For contactors servicing yard zones, surge arrestors are required on the catenary side of the contactor to protect the upstream contactor and ground switch system. Each ground switch must be housed in an enclosure at operator height such that its position can be viewed to confirm ground switch position. Control and PLC systems should be housed at operator height.

6.2.16 Cable Splices and Terminations

Cable splices must use approved splice kits and conform to CSA C22.2 No 188 [49] and CSA C22.3 No 1 [50]. Cable splices must not reduce the rated ampacity of the conductor.

Terminations must be mechanical compression fitting connectors or mechanical lugs with a rated ampacity equal to or greater than the conductor. All insulated cable terminations must be protected with appropriate heat shrink tubing.

6.3 DUCT BANKS AND RACEWAYS

General design requirements for raceways and duct banks used in the TPS include:

- Underground supply feeders must be installed in minimum 102 mm diameter concrete encased PVC or DB2 ducts
- Tunnel supply feeders must be installed in minimum 102 mm diameter RTRC
- At least one spare conduit must be installed for each positive feeder and two spare conduits must be installed for each Negative Circuit Feeder (NCF) with nylon pull strings in each spare duct
- Inside the TPSS, positive and negative feeder cables must be run in non-metallic trays meeting NFPA 130 [17] requirements, or RTRC. Installations in cable trays must accommodate cable spacing to maximize cooling
- For underground ducts under the UC foundation the ducts may be direct buried if determined suitable by the Designer, otherwise ducts must be concrete encased.
- For direct buried duct application, appropriate compaction material to protect the ducts and achieve the desired compaction must be used.

For more specific information regarding TPS duct bank and conduit requirements, refer to Chapter 11, Electrical.

6.4 OVERHEAD TRACTION POWER SYSTEM

The Overhead Traction Power System (OTPS) distributes DC power from TPSS to the LRVs operating on Mainline tracks, Yard Tracks, and within shop or maintenance facilities. The OTPS primarily consists of an OCS, physical support subsystem and a feeder subsystem.

6.4.1.1 Overhead Contact System

The OCS consists of conductors, including contact wire and any supporting messenger wire, jumpers, fixed and auto-tensioned terminations, in-span fittings and associated hardware located over the track. It is from these devices that the LRV collects power through contact between the pantograph and the contact wire (refer to Appendix 6A Figure 6.4).

The LRT System is electrified by a minimum of one contact wire typically supported from, and Bonded to, a messenger wire. In tunnel areas, the messenger wire runs parallel to, but separate from the contact wire. Messenger wire sizes vary from 4/0 to 500 kcmil and existing contact wire size is 4/0 to 350 kcmil. Where the OCS has electrical support challenges, additional conductors may be installed overhead or underground, although additional overhead conductors should not be used for new extensions. Current return circuit is through the rails.

A Contact Wire Auto Tension (CWAT) or Simple Catenary Auto Tension (SCAT) system is used in open corridors. The SCAT system includes the contact wire suspended from a messenger wire centred over the track by wire clips and insulated brackets. In both underground tunnel and open corridor construction, the contact wire is staggered on either side of the pantograph centreline for even pantograph wear. Positioning of the messenger wire in open corridors must be determined by the OCS Designer to best support the position of the contact wire. For tunnel applications, messenger wire must be located on the opposite side of any Designated Egress Walkway.

6.4.1.2 Support Subsystem

The support subsystem consists of all infrastructure required to keep the OCS in position above the track. This includes foundations, poles, down haul anchors, insulators, cantilever head spans, and any other assemblies and components required to support the OCS. The support subsystem must conform to the designed configuration and allowable loading, deflection, and clearance requirements.

6.4.2 Design Philosophy

Designs must minimize visual impact and achieve an acceptable level of SUI as provided in Chapter 14, Urban Integration, while considering the corridor type as provided in Chapter 1, General, and meeting system performance requirements. Consideration must be given to blending the appearance and style of pole, and its size, shape, colour, and location into the adjacent communities. Designs should include components that are standard and off-the-shelf to reduce material and installation costs, must have proven performance, and must maintain functionality during extreme weather conditions and temperature changes.

In addition, the Design must consider existing overhead obstructions such as bridges, overpasses, buildings, and aerial utilities that may impact the final layout.

6.4.3 Design Requirements and Criteria

All applicable requirements from Codes, Standards, and Guidelines provided in this chapter must be considered in the Design. Summaries of design requirements are presented in the following sections.

6.4.3.1 Overhead Contact System Design Operating Speed

Speed criteria that must be used in the design of the OCS[2] are provided in Table 6.2.

Table 6.2 OCS Mainline and OMF Design Operating Speeds

Mainline	
Maximum OCS design speed	90 km/h
Maximum LRT design speed	80 km/h
Maximum LRT operating speed	70 km/h
Maintenance and Storage Yard	
Maximum OCS design speed	30 km/h
Normal yard operating speed	10 km/h (test track is 40 km/h)

Critical Speed

Critical speed is defined as the LRV speed at which resonance is generated on the OCS wires resulting in uncontrolled vertical movements of the pantograph. The OCS must be designed so critical speed is in excess of 100 km/h. Reduced critical speed is permitted in areas such as crossovers that have a restricted operating speed. In these areas, the critical speed must be at least 1.5 times greater than the LRT operating speed.

6.4.3.2 Operating Temperature

OCS equipment in open corridors should be designed for an operational temperature range in accordance with Chapter 1, General, and in tunnels as determined by the tunnel design.[3]

6.4.3.3 Operating Wind Speed

The OCS system must be designed for normal operation in wind speeds of 95 km/h and pressure of 450 N/m^2 without ice loading, at an exceedance probability of once in 50 years. These values must be used for quantification of dynamic wire displacements with respect to the dynamic centreline of the pantograph.

Where LRT Systems are placed on high embankments, elevated bridges, elevated overpasses, or on flat open areas, the normal operating wind speed should be increased by an exposure factor as outlined in C22.3 No. 8 [16].

6.4.3.4 Pantograph

The pantograph is the current collector mounted on top of an LRV. This spring-loaded device produces a constant upward force on the contact wire throughout its operating range. The response to changes in elevation deteriorates in the lower operating ranges. The following pantograph related dimensions are for the two existing types operating on the LRT System and are for information only. The Designer must confirm applicable pantograph operational characteristics with the Engineer for each project. General operational characteristics for the U2 LRV pantographs are listed in Table 6.3 and for the SD-160 LRV pantographs in Table 6.4.

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[2] OCS speed criteria differ from speed criteria provided in Chapters 2, 4, and 5. The speed criteria given in those chapters relate to track design.

[3] The temperature ranges for tunnel sections are dependent on tunnel length, depth, proximity to stations and portals, and if both tunnels are open ended.

Table 6.3 Siemens U2 LRV Pantograph Operating Parameters

Parameter	Value
Nominal static upward force	93 N
Standard operating range	3970 mm to 7170 mm above TOR
Height of pantograph in the down position	3870 mm above TOR
Total length of carbon strip	1000 mm (operating width)
Total length of pantograph	1700 mm
Total width of carbon strip	35 mm
Total depth of carbon strip	18 mm

Table 6.4 Siemens SD-160 LRV Pantograph Operating Parameters

Parameter	Value
Nominal static upward force	93 N
Standard operating range	3960 mm to 6880 mm above TOR
Height of pantograph in the down position	3785 mm above TOR
Total length of carbon strip	1081 mm (operating width)
Total length of pantograph	1700 mm
Total width of carbon strip	66 mm
Total depth of carbon strip	18 mm

A pantograph experiences dynamic lateral displacements and rotations from its static centreline position due to pantograph flexure, dynamic vehicle sway and track tolerances.

Design of overhead contact wire layout must consider dynamic movement of the LRV in accordance with the DVDE (refer to Chapter 3, Clearances and Right-of-Way). Required clearances for an LRV at the OCS supporting structures and in space-restricted areas, such as tunnels, must be met. Clearances must also be met considering an unworn pantograph in both static and dynamic conditions.

6.4.3.5 Conductor Characteristics

Contact wire must be a minimum grooved alloy 80 as per ASTM B9 [51]. Copper cadmium alloy and hard drawn copper must not be used for contact wires. A single contact wire with a maximum size of 350 kcmil should be used.

Messenger wire must be stranded hard drawn copper as per B105 [52], ASTM B8 [53], and ASTM B1 [54] with a minimum size of 500 kcmil.

Some existing sections of the LRT System have a separate parallel messenger wire to provide increased electrical support for the system. Parallel messenger wires should not be used in new Designs.

6.4.3.6 Design Loads

Structural components of the overhead electrical system (poles, foundations, anchors) must be designed according to the Canadian Highway and Bridge Design Code (CHBDC) [3] and Overhead Systems [50], using limit state design. Provisions in CHBDC [3] are applicable to OCS structures (poles, foundations, anchors) unless otherwise accepted by the Engineer.

The design of structural components including contact wires, feeder wires, poles, foundations, span wires, support arms, and all associated fittings and connections must include standard load cases outlined in Ultimate Load States (ULS) as follows:

Load Case 1: Heavy Ice and Wind Loading

- Temperature: -20° C
- Wind: 450 Pa (1:50 year wind – 95 km/hr)
- Ice Accretion: 12.5 mm

Load Case 2: High Wind Loading

- Temperature: 0° C
- Wind: 1020 Pa (1:100 year wind with gust factor of 2)
- Ice Accretion: none

Dead loads must be included in each load case.

Wind loads must be applied in the direction that produces maximum stress in combination with other loads and must be applied on the increased diameter of wires due to accretion of ice. Effects of wind drag must be added to the wind loads specified above. Wind drag coefficients for slender structural elements must be as per CHBDC [3]. Where the LRT Trackway is placed on high embankments, elevated bridges, or elevated overpasses, the design wind load must be increased by an appropriate exposure factor.

Loads caused by wire tension and radial loads caused by wire pull-off and stagger must be included in each load case. Variations in wire loads due to temperature changes must be adequately considered in all cases. Variations in loads during erection and maintenance must be adequately considered for safety.

The Designer must outline the method used to design structural components of overhead systems and state any specific code references, factors used, assumptions, and ultimate safety factors used in the Design.

6.4.3.7 Contact Wire Wear

The contact wire experiences mechanical wear from passing pantographs. As the wire cross-sectional area decreases there is a reduction in ultimate breaking strength, an increase in electrical resistance, and a decrease in physical clearance to clamps and other OCS hardware. The contact wire wear used in the Design must not exceed a 30% wear limit.

The OCS Designer must identify the minimum contact wire thickness and confirm that the expected performance of the contact wire is not impeded. The following constraints must be balanced to determine the acceptable minimum value:

- Contact wire tensile stress must not exceed 50% of the ultimate breaking strength of worn wire (a factor of safety of at least 2.0)
- Adequate physical clearance to clamps and other OCS hardware must be provided
- Increased electrical resistance of the wire must be considered
- Contact wire depth must not be reduced by more than 30% of the new wire cross sectional area

All modeling or analysis in the design of the TPS that considers the contact wire must use the characteristics of a fully worn contact wire.

For each unique contact wire installation, an equivalent contact wire thickness for maximum wear must be provided. Tensile strength testing must be performed as required to confirm predictions of strength in the worn condition.

The tensile safety factor of at least 2.0 also applies to the messenger wire.

6.4.3.8 Contact Wire Layout

The height and alignment of contact wire is dictated by the dynamic envelope of the LRV pantograph, which is dictated by the elevation, superelevation, and alignment of the LRT tracks.

The OCS Designer must coordinate the contact wire layout with the track Design.

The OCS Designer must consider superelevation when laying out curve movements. If superelevation does not fully balance curve movement, the contact wire layout must accommodate vehicle sway due to centrifugal forces.

6.4.3.9 Contact Wire Height

The pantograph operating range dictates the allowable range of contact wire heights. The absolute minimum contact wire height above Top of Rail (TOR) must be 4200 mm. The contact wire heights applied through the LRT System must also consider the system voltage level while meeting the requirements outlined in CSA C22.3 No. 1 [50]. Contact wires must be installed within the standard maximum and minimum nominal heights shown in Table 6.5. If special circumstances require contact wire heights outside of this range, the Engineer must be consulted as speed restrictions may be necessary.

Table 6.5 OCS Contact Wire Operating Heights

Contact Wire Height	Height above TOR
Absolute Minimum	4200 mm
At-Grade and Elevated Minimum	4800 mm
Minimum at Road Crossings	5800 mm
Maximum Nominal	6500 mm

6.4.3.10 Contact Wire Gradient

The contact wire gradient is defined as the rate of change in elevation of contact wire with respect to the TOR. Where practicable, the contact wire grade should match the grade of track for a contact wire gradient of zero.

The recommended maximum gradient as per CSA C22.3 No. 8 [55] is presented in Table 6.6. The gradient must not exceed 2.0% (1:50) under any circumstances. The change in gradient in adjacent spans must not be more than half of the maximum gradient.

Table 6.6 OCS Contact Wire Gradient and Speed Restrictions

Speed	Maximum Gradient
Yard (10 km/h)	2.0% (1:50)
50 km/h	1.3% (1:77)
75 km/h	0.8% (1:125)
90 km/h	0.67% (1:150)

6.4.3.11 Clearances

Electrical Clearances

Electrical clearances must meet CSA C22.3 No. 1 and C22.3 No. 8 requirements and must satisfy the operational limits of the LRVs and related maintenance equipment. Any other standards or codes applied by the Designer must be reviewed and accepted by the Engineer. Where clearances recommended herein differ from minimum requirements of the current codes, the more restrictive values must govern. Refer to the applicable figures in Chapter 3, Clearances and Right-of-Way along with Appendix 6A Figure 6.5.

The normal static air clearance between electrically energized parts and grounded structures must be 400 mm, but may be reduced to 100 mm if energized parts are rigidly supported by insulators at these locations.

Static clearance is defined as the clearance to a stationary wire. Dynamic clearance is the clearance to a wire while it is in motion or is displaced by the passing pantograph or wind loads. The clearances are most applicable in tunnel applications but may be required in open corridor applications where the OCS is attached to an overhead structure such as a Station pedway. Table 6.7 provides the minimum electrical clearances for wires in both static and dynamic states.

Table 6.7 OCS Contact Wire Static and Dynamic Clearances

Standard Clearances	Static	Dynamic
Contact Wire to Tunnel Overhead Structure	400 mm	300 mm
Feeder Wire to Tunnel Structure	100 mm	N/A
Any OCS Wire to Any Installed Hardware	500 mm	400 mm

Catwalk, Stairway, and Readily Accessible Area Clearances

Walkways, Catwalks, and stairways must be kept at a safe distance from the OCS as per Figure 6.5.. Examples of areas in proximity to the overhead wires that are subject to these clearance requirements are:

- Platforms, stairways, and escalators
- Regular Patron access areas
- Emergency Egress Walkways
- Catwalks in bored (round) tunnels
- Passages and Platforms accessible to maintenance personnel

The minimum required clearances between energized conductors and accessible areas must be observed. Catwalks and stairways in the vicinity of the OCS must be guarded with proper handrails and railings. Metal handrails and railings must be electrically bonded and grounded. Bonded and grounded metal parts must be at least 2600 mm from a Platform edge.

Mechanical Clearances

OCS support locations are fixed and are entirely dependent on track alignment. A large number of OCS mounting brackets are generally required which may impact the location of civil, architectural, and mechanical equipment, particularly in tunnels and Stations.

Space above the DVDE and below the top of the tunnel or structure ceiling is reserved for OCS installations. Equipment being considered for installation in this space must be coordinated with the OCS

Designer. Pipes, ducts, or cables accepted for installation on the ceiling must cross at right angles to tracks.

Equipment Restrictions

Non-TP equipment must not be installed above the OCS. Non-TP equipment close to overhead wires must have adequate clearance from energized parts to avoid the need for de-energization during maintenance activities.

If non-TP equipment is installed above the OCS, maintenance or repair of this equipment will require de-energizing of the overhead wire system to gain access and may require removal of the OCS.

Underground Utility Clearances

Minimum clearances between OCS poles and anchor foundations and underground utilities must comply with CSA C22.3 No. 7 [56] and the Alberta Electrical Utility Code [57].

Chapter 17, Utilities and Drainage also provides minimum clearances for utilities to the edge of the LRT ROW. The Designer must evaluate those clearances as they relate to pole and anchor foundation placement and apply the higher clearance when comparing to those listed below.

Recommended clearances are shown in Table 6.8. Where there is a difference between these guidelines and the code, the greater clearance must govern.

Table 6.8 Minimum Pole and Anchor Foundation Clearances to Underground Utilities

Object	Clearance
Water Mains and Water Service lines	1.5 m
Gas Lines and Services	1.5 m
Underground Power Cables	1.0 m
Underground Communication Cables	1.0 m

If minimum clearances cannot be met, the Designer must coordinate reduced clearances with the appropriate utility agency early in the design process.

OCS Pole Clearances – Tangent Track

The minimum clearance from centreline of track to face of OCS pole must be 2070 mm[4], while the minimum clearance to balance weights on an OCS pole in worst case BWA swing position must be 1995 mm.

OCS Pole Clearances – Curved and Superelevated Track

Additional clearance to that stated for tangent track is required on curves to account for out-swing of vehicle ends, for in-swing of vehicle and for vehicle rotation from vertical due to track superelevation, as provided in Chapter 3, Clearances and Right-of-Way.

[4] This is based on track separation of 4500 mm, allowing for a range of pole diameters and installation tolerances. The balance weight clearance is an absolute minimum and greater separation should be provided to promote safe refuge for maintenance personnel, space permitting. See Chapter 3, Clearances and Right-of-Way.

6.4.4 OCS – General

All contact wire support components must be designed to provide elastic suspension of contact wire to permit it to deflect upwards under influence of applied upward pantograph pressure. Development of “hard spots” or vertically rigid suspension points in the OCS must be avoided.

Where a messenger wire is used in a simple catenary configuration, it acts as a support wire to carry the contact wire in a level profile relative to the track. Contact wire is supported by dropper wires suspended from catenary messenger wire at specified minimum intervals. Some open line areas use a contact wire only configuration to reduce the visual impact of the OCS conductors.

In tunnel areas, messenger wire is typically mounted to the tunnel ceiling structure on stack insulators and carried in a straight alignment to one side of the contact wire which is supported on elastic tunnel support arms. The tunnel support arms are specialty-manufactured devices that allow for controlled vertical movement of the contact wire to provide an elastic suspension.

6.4.4.1 Tensioning Systems in Use

Wind blow-off of contact wire is directly related to tension in the contact and catenary messenger wires. Also, the allowable maximum operating speed of the system is limited by the critical speed, which is directly proportional to wire tension. Due to large variations in ambient temperature and wire heating, variable tension wires are subject to excessive variations in tension. As a result, auto tension (or constant tension) open line catenary systems provide more predictable dynamic characteristics and are more reliable than variable tension open line systems constructed with fixed dead ended wires. Auto tension systems use balance weight tensioning assemblies or springs to maintain constant wire tension.

An auto tension simple catenary with balance weights is the standard for open corridor LRT lines. An auto tension contact wire with balance weights is the standard for tunnels.

Variable tension, fixed wire systems are accepted as an alternate method of construction for use in long tunnel applications with a narrow ambient temperature range and short contact wire spans. Fixed dead ended lines with variable tension must not be used for open corridor catenary applications.

SCAT System

The SCAT system consists of a single messenger wire supporting the contact wire, which is hung underneath. Tension is maintained throughout its tension length using Balance Weight Assemblies (BWA) or spring tensioning assemblies. The wire is fixed at mid-length by a mid-point assembly preventing shifting to either end of the line.

The standards for tensioning systems are:

- For open Trackways – the tension on the simple catenary system with balance weights is constant at 1100 kg and 1300 kg, for messenger and contact wires respectively
- For tunnels – the tension on the contact wires with balance weights is constant at 1050 kg or ranges from 600-1000 kg where a spring tensioner is used

SCAT open line catenary systems provide more predictable dynamic characteristics and are typically more reliable than variable tension open line systems constructed with fixed dead ended wires.

CWAT System

The CWAT system consists of a single contact wire, auto tensioned without a supporting wire above. Tension is maintained throughout its length using Balance Weight Assemblies (BWA) or spring tensioning assemblies. The wire is fixed at mid-length by a mid-point assembly preventing shifting to either end of the line.

The standards for tensioning systems are:

- For open Trackways – the tension on the contact wire only system with balance weights is constant at 1360 kg, typical for 350kcmil contact wire systems
- For tunnels – the tension on the contact wires with balance weights is constant at 1050 kg or ranges from 600-1000 kg where a spring tensioner is used

CWAT open line catenary systems provide more predictable dynamic characteristics and are typically more reliable than variable tension open line systems constructed with fixed dead ended wires.

Fixed Termination System)

This system differs from the SCAT and CWAT systems in that the wire changes tension with temperature variation. It may be an acceptable method of construction in long tunnel sections with narrow ambient temperature ranges and short contact wire spans. It should not be used for open Trackways and its use should be limited to areas where auto tensioning is not practicable and environmental conditions minimize wire tension changes.

A second messenger wire may be added to a SCAT design to provide improved power and voltage support. This second messenger wire is attached on the OCS poles and is not auto tensioned.

6.4.4.2 Wire Tension

The Designer must consider the following factors when choosing a wire tensioning system and the corresponding wire tension:

- Allowable maximum operating speed of the system is limited by the critical speed, which is directly proportionate to wire tension
- The ability of wind to blow contact wire off a pantograph (wind blow-off effect) is directly related to tension in contact and catenary messenger wires
- Tension must not exceed the 50% of the ultimate strength of a worn conductor

6.4.4.3 Wire Tensioning Equipment

The wire tensioning system must be designed to the maximum operating temperature identified in the Load Flow Study. The system can consist of either BWA or spring tension equipment, with due consideration for effects of wire heating under design loading. Wire tensioning assemblies must be mounted out of running one span away from the overlap transition span, either inboard or outboard of the tracks, supported with standard anchorage assemblies. Designed tension length is limited by available spring or balance weight operating ranges and rotational range of the OCS support arms.

Balance Weight Assembly

The current typical balance weight tensioning equipment used on the LRT System is a tension wheel assembly that uses different diameter drums to produce a 3:1 mechanical advantage. The balance weight required is therefore one third of total line tension supported, and vertical movement of the balance weight stack is 3 times greater than thermal expansion of attached OCS wires.

Balance weights must be made of a material suitable for the exterior operating environment provided in Chapter 1, General and must be weather and corrosion resistant. Balance weights must be mounted on the exterior of the pole except where internal weights should be used due to SUI requirements. All mounted weight stack must be designed to provide required mechanical clearances during all operating conditions and provide a guide path for weight movement and maintenance access. In areas where OCS poles are readily accessible by the public, or an important design consideration is achieving an acceptable level of SUI, as provided in Chapter 14, Urban Integration, the balance weights must be hidden and protected from public access.

The Designer must provide BWA setting information encompassing all operating, installation, and maintenance conditions for each BWA location.

Spring Tensioners

Conventional spring tensioners are suitable only for very short tension lengths, such as crossovers, where there is a speed restriction. Spring tension is typically in the range of 600 kg to 1000 kg depending upon ambient temperature.

Newer spring tensioner designs use spiral springs and eccentric discs to apply a constant tension over a greater compensation length. If compatible with Edmonton's operating environment, these may be considered as an alternative to BWA.

6.4.4.4 Mid-Point Anchors

The mid-point of each tension section must be sufficiently anchored to restrict cantilever arm rotation. These Mid-Point Anchors (MPA) function as the end anchorage point for a tension length and are essential for proper operation of the automatic tensioning equipment. The Designer must locate an MPA to provide the required anchorage for the adjacent tension sections. On open Trackways, the mid-point cantilever arm should be anchored where the messenger wire attaches to it. In tunnels, the MPA should be anchored to the tunnel ceiling.

6.4.4.5 Terminations or Dead Ends

OCS wires must be terminated or dead ended on freestanding or anchored poles, retaining walls, buildings, ceilings, bridges, or other fixed infrastructure. Two types of terminations may be used:

- Fixed termination[5] – where the wires are attached directly to supporting structures
- Constant tension termination – where the wires are connected to an auto tensioning device

Double insulation points must be provided for all OCS wire terminations. Line insulators must be rated for 15 kVac. All wire fittings, connections and insulators must have a tensile strength greater than the rated tensile strength of the wire supported. Functional interference with servicing equipment used for maintenance purposes must be avoided. Turnbuckles must be installed on the structure side of the line insulator.

Dead end and associated structures at end of line should be located with consideration for future expansion. These structures should not conflict with the future track's DVDE.

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[5] Special attention must be given to wires that terminate on structures that are occupied by the public or have vehicular or pedestrian traffic loading. All safety issues must be examined relative to structural, electrical, and mechanical clearance requirements.

6.4.5 Overhead Contact System Configurations

6.4.5.1 Tension Length and Tension Section

Tension Section

A tension section is defined as length of wire between two tensioning devices that keep the OCS wires at constant tension. An MPA is installed at the middle of a tension section to partition each tension section into two tension lengths. A tension section may also consist of a length of OCS between a fixed dead end and tensioning assembly.

Tension Length

Tensioning length is the length of OCS wire between the MPA (or fixed termination) and the tensioning device (BWA or spring). The tension length is restricted by the following:

- Allowable thermal expansion of contact and messenger wire
- Height of the support pole and maximum vertical displacement for BWA
- Compensation range for springs
- Steady arm rotation
- Tension limits on the wires

The Designer must specify maximum tension length for all new OCS installations with due consideration for the effect of conductor heating under the design loading identified in the Load Flow Study, including solar effects. The overhead on each line must be mechanically independent from each other and from interfacing tracks and sidings.

6.4.5.2 Span Lengths

The OCS Designer must determine the applicable maximum span lengths on tangent and curved tracks for each OCS configuration (see CSA C22.3 No. 8 [55]based on the following:

- Contact and messenger wire tension limitations, including sag
- Contact wire displacement limits and allowable wind blow-off
- Minimum separation of 150 mm between messenger and contact wire at midspan to accommodate dropper wires if applicable
- Radial loads on structures
- Cost optimization

In general, the existing maximum simple catenary spans allowed is 58 m. For tunnel construction, the existing maximum spacing between elastic supports is 11 m.

6.4.5.3 System Depth

System depth is defined as the separation between messenger and contact wires at the point of support. The existing nominal system depth is 900 mm with 4/0 messenger wire and 1600 mm with 500 kcmil messenger wire.

The design of nominal system depth must consider wire size, wire tension, span length, dropper lengths and must include a minimum separation of 150 mm between contact and messenger wires at mid-span. Depth should be optimized based on economic and technical criteria.

6.4.5.4 Contact Wire Stagger

To avoid overheating and promote uniform pantograph wear, the contact wire must be continuously staggered from pantograph centreline. Stagger should be as wide as practicable while remaining on the operating width of the pantograph's carbon current collector and allowing for permissible displacement.

Sections of unstaggered wire may be used at overlap transition spans. The length of unstaggered wire should be minimized and should not be in an acceleration zone.

Range of stagger must be confirmed through a pantograph security analysis conducted by the Designer considering dynamic horizontal movement of the pantograph. This analysis must identify maximum stagger values in tangent and curved track sections at the maximum contact wire height. The existing LRT System uses a nominal stagger of 200 mm and for curved track a maximum of 250 mm to the outside of the curve at each support.

Since the dynamic lateral displacement of the current collector increases as the contact wire height increases, proportionally narrower stagger arrangements must be used for contact wire heights in excess of the nominal maximum. The nominal contact wire stagger must not be less than 100 mm. Installation tolerances of contact wire stagger must not exceed ±10 mm.

6.4.5.5 Pantograph Security Analysis

The OCS Design must include a pantograph security analysis to confirm that contact is maintained between the contact wire and pantograph carbon collector. Displacement of the contact wire from centreline of the pantograph must not exceed half the width of the pantograph carbon collector, including stagger, wind blow-off, stagger effect, Δ-stagger, and pantograph sway due to vehicle dynamics, track tolerances, and pantograph flexure.

In addition to stagger, the contact wire will experience dynamic displacement from its static position at mean temperature. The effects described below must be included in the pantograph security analysis.

Wind Blow-off and Stagger Effect

Contact wire wind blow-off, caused by wind pressure acting on the OCS wires without ice accretion, must be considered as maximum at midspan, and zero at the steady arm support. Stagger effect is considered as the portion of contact wire horizontal wind deflection from the support point and beyond design stagger. Stagger effect must be considered between the support and mid-span for staggered wires and at midspan for un-staggered wire.

Stagger Change (Δ-Stagger)

Stagger change due to the increase in wire stagger (Δ-stagger) produced by rotation of the contact wire support cantilevers during thermal expansion and contraction of the catenary and contact wires in auto tensioned systems must be considered.

Pole Deflection

The impacts of OCS support pole elastic deflection on the transverse displacement of the contact wire must be considered in the pantograph security analysis. The direction of wind and subsequent pole deflection must be assumed to occur in any direction.

6.4.5.6 Overlap Transition Spans, Crossovers, and Turnouts

An overlap transition span is an area where one OCS tension section ends, and another begins. Both tension lengths are anchored out of running inboard or outboard of the tracks. The two tension lengths run parallel to each other where the pantograph makes the transition from one tension section to the next. This overlap region is referred to as the transition span.

Where crossovers exist, a separate tension length must be provided for the crossover track. The crossover tension length runs parallel with the main line in an overlap region before being anchored out of running either inboard or outboard of the tracks.

An overlap transition must be designed to provide a smooth transfer of pantograph from one contact wire to the next over the overlap length. Overlap must also accommodate maximum differential thermal movements of the tension sections in the overlap region. An existing typical overlap length is 2 m which can be achieved using double poles or a double arm bracket mounted on a single pole.

Potential equalizing jumpers must be provided at transition spans to prevent arcing during pantograph transfer between sections. Adjacent catenaries must be connected with full cross-section copper jumpers to provide electrical continuity where required. Jumpers must accommodate differential thermal movements of the catenary and contact wires.

For OCS serving track crossovers and turnouts, wires must be mechanically independent of the main line tension section. Section isolators located in crossovers must provide adequate clearance from the pantograph movements in all adjacent tracks. Transition span poles must be accurately located to achieve the correct alignment through the crossover. OCS support poles must be set back from the divergent track to provide clearance to the DVDE.

6.4.6 Overhead Contact System Support Components

In support of the City's Urban LRT Charter the Designer must recognize the need to blend and integrate OCS support components to achieve an acceptable level of SUI as provided in Chapter 14, Urban Integration, while considering the corridor type as provided in Chapter 1, General. Meeting this objective will require a high level of coordination with the Engineer.

Guidelines for design of the components that support the OCS are presented in this section. For every arrangement of contact and catenary wire support, two levels of full rated insulation must be provided between electrified wire and a grounded support structure.

Hardware should be of ferrous material and hot dip galvanized. Alternative materials may be permitted at the discretion of the Engineer provided the material is non-corrosive or has an adequate protective coating. Special precautions must be taken to prevent bi-metallic corrosion at points where dissimilar metals may come into contact.

6.4.6.1 Poles

New construction must use straight octagonal shaped poles to support an OCS on the existing LRT System. All poles and related elements must be galvanized inside and out to prevent corrosion, and pole designs must include provision for drainage of moisture from any hollow sections.

Other infrastructure should not be supported on OCS poles in the Design unless those requirements cannot be met without unacceptable SUI or land acquisition impacts. Design coordination is required between other disciplines to evaluate the need for shared use poles. Refer to Chapter 14, Urban Integration for more details.

If shared use poles are required, the OCS Designer must coordinate the pole design with the Engineer and other Owner stakeholders.

For poles housing multiple circuits, the Designer must consider the use of mechanical segregation between circuits within the pole.

OCS poles may be located between or on the outside of tracks (refer to Appendix 6A Figure 6.6).

Standard Classes of Overhead Contact System Poles

Pole design requirements vary by application on tangent or curved track sections for different loads including:

- Single cantilevers
- Double cantilevers
- Weight tensioning and dead-end structures
- Double arm transition span structures

These examples are illustrative only. Poles must be designed in different strength classes to optimize economics of the LRT System.

Design Loads

OCS Poles must be designed to withstand the following load conditions:

- Effect of gravity acting on all components
- Wind acting on wires, cantilever arms, and the pole shaft
- Ice accumulation on wires
- Longitudinal, radial and stagger components of wire tension
- Dynamic effects
- Extreme variations in temperature
- Erection and maintenance considerations

Design loads must be applied in combination to produce maximum stress levels. Poles must be designed with sufficient reserve capacity to allow for future installation of additional loads that may be introduced as the LRT System is extended or service is expanded. This additional reserve capacity must be determined in consultation with the Engineer.

Overhead Contact System Pole Deflection Limits

Poles must be designed with enough stiffness to ensure reliable operation of LRVs under dynamic conditions. Calculation of deflection due to dynamic conditions must be based upon un-factored loads. At the nominal design contact wire height, the maximum dynamic deflection of poles perpendicular to the track must not exceed 50 mm, due to wind only.

Materials and Finish

OCS poles must be manufactured from new materials only and must be constructed from structural quality steel as per CAN/CSA-G40.21 [58], and CAN/CSA-G40.20 [59] or an approved equivalent.

To reduce maintenance costs and maximize the life of the OCS system, OCS poles must be galvanized as per CSA G164 [60] with a minimum coating density of 610 g/m^3.

Painted or powder coated OCS poles, as determined by SUI requirements, must comply with the Owner’s Road and Walkway Lighting Construction and Material Standards.

Standard Pole Details

For new construction, nominal pole heights must be equal where practicable.

Standard cantilever poles must be octagonal in cross-section and non-tapered to accommodate attachment of standard cantilever arms and tensioning assemblies.

Standard poles must be constructed as a single piece shaft. Transverse shaft welds are not permitted except to join the shaft to its base plate.

Feeder lateral poles must be constructed with feeder conductors routed through the mast interior. Cable openings and hand holes in the pole must be reinforced to prevent reduction in flexural capacity of the shaft at the opening locations.

OCS poles with internal balance weights must be constructed with adequately sized openings to house and mount the BWA and include an inspection/adjustment access panel. These openings must be reinforced to prevent reduction in flexural capacity of the shaft at the opening locations.

Base plates must be designed with a square 4-hole bolt pattern. The overall bolt circle diameters must conform to existing Owner pole standards where practicable. The pole must bear directly on the concrete surface.

Surface drainage must be directed away from OCS poles, and each pole must have a weep hole or approved equivalent method to prevent water being trapped inside.

Overhead Contact System Pole Foundations/Anchor Bolts

OCS pole foundations must be drilled, cast-in-place, steel reinforced concrete piles with anchor bolts to attach to the pole. Anchor bolts, nuts, and washers must be galvanized. A geotechnical investigation must be carried out to provide soil parameters for the foundation design. Poles may be mounted on bridge decks or structurally reinforced slabs when pile foundations are not practicable. Pole bases must have provision to level the poles and must provide a drainage port for any water buildup inside the poles.

OCS pole and anchor foundations must be designed with four anchor bolts to attach the structure to the concrete base. Anchor bolts must be constructed from high strength round steel bars. The Designer must coordinate the design of the pole with the material grade and diameter of the anchor bolts. Anchor bolts must be designed such that the pole shaft will fail in bending about any axis prior to yielding of the anchor bolts. Structural requirements for catenary pole supports are provided in Chapter 9, Structures.

The anchor bolts must be designed to support the OCS pole base directly bearing on the concrete surface. Prior to placement, all anchor bolt assemblies must be dimensionally tested with an accurate base plate template to confirm that the bolt pattern matches the pole base plate hole pattern[6].

Overhead Contact System Pole Anchors

Pole anchors should not be used unless bending resistance to longitudinal loads cannot reasonably be provided in the OCS pole design. If pole anchors must be installed in a location that will expose them to the risk of damage from vehicles or equipment, protective measures such as concrete filled steel bollards

[6] The Designers of the pole foundation and the OCS pole must coordinate the interface between the two elements.

must be installed to protect the anchor from impact. Protective infrastructure must be a minimum of 1.0 m in height and must be painted a bright contrasting colour.

Overhead Contact System Pole Identification

Every OCS pole must be labelled with a unique identifier as per the Operator's existing labeling convention. Identifier labels must be reflective and must be visible to the Train Operator in normal operating direction. Center mounted poles must have a label on both sides.

6.4.6.2 Cantilever Arm Assemblies

In its static position, the contact wire steady arm must be sloped downwards from horizontal and must pivot at the arm strut connection to allow differential movement of contact wire and catenary messenger wire.

The steady arm must be designed to accommodate a maximum contact wire uplift of 100 mm while maintaining 15 mm minimum dynamic clearance to a fully worn pantograph.

The cantilever arm must clear the pantograph with adequate allowance for dynamic lateral displacement of the pantograph due to dynamic vehicle motion, track tolerances, and pantograph flexure.

The cantilever arm pole attachment must be hinged to facilitate longitudinal movement due to thermal expansion and contraction of catenary and contact wires. Cantilever arms should be clamped, rather than bolted to the mast to accommodate varying wire heights and system depths, and to facilitate arm adjustment.

The OCS Designer is responsible for specifying the application of standard cantilever arms and for designing any non-standard cantilever arms as required.

6.4.6.3 Tunnel Supports

Elastic/Resilient Arms

Elastic or resilient tunnel arms are specially manufactured devices that allow controlled vertical movement of the contact wire to provide an elastic suspension. Tunnel arms must pivot to allow arms to rotate with wire expansion and contraction due to temperature changes. Tunnel arms must be attached to the tunnel structure with rigid brackets configured for the particular tunnel geometry, or mounted directly to the structure. All tunnel arm support brackets must be bonded together and attached to the tunnel OCS ground system. Each arm must include a label with a unique identifier as per the Operator's labeling convention.

Overhead Conductor Rail

Overhead conductor rail is not currently in use in the LRT System but may be considered if compatible with the local climate, system conditions, and is both economically and functionally beneficial. The Engineer must be consulted prior to the design of a conductor rail system.

6.4.6.4 Span Wire Suspensions

OCS conductors may be suspended from a span wire in shops, yards, tunnels, tight curves and other locations where space is limited. Depending upon the application, head span or crossover spans may be used. Backbone span wires may be used to support pull-offs through small radius curves.

Contact wires should not be rigidly attached to span wire supports. Messenger wire may be rigidly attached to the span wire and positioned to clear the dynamic profile of the pantograph. All connections to electrified wires must be completed with a rated insulated fitting. Two levels of insulation must be provided between an energized wire and either a grounded structure or the energized wire of another circuit.

6.4.6.5 Attachments to Grade Separation Structures

The OCS may be attached to structures when the LRT is At-Grade and a vehicular or pedestrian bridge passes over it, the LRT is routed below the surrounding ground level to pass under a structure carrying vehicular and pedestrian traffic, or the LRT is carried on a structure above the vehicular and pedestrian traffic. Design requirements for structures are provided in Chapter 9, Structures.

Design Considerations

All electrified components must be isolated from any structures or supports. All attachment wires must have at least two levels of insulation, and any conductors attached to the roof of a structure must be mounted opposite an Emergency Egress Walkway. An insulating material must be used between the underside of a bridge deck and the OCS.

The potential for the contact wire swinging from its normal position should be mitigated.

All electrical clearances must be as per CSA C22.3 No. 8 [55] and CSA C22.3 No. 1 [50] pursuant to the Alberta Electrical Utility Code [57] and all exposed metal must be securely grounded.

Protective screening must be provided where pedestrians may be near the OCS.

Protective Screening Device (Shroud)

Where the LRT is constructed below bridge structures or buildings, screening and/or fencing must be provided where wires enter and leave the structure. This screening is to protect the OCS wires from damage and to protect the public from accidental contact with an energized wire. A minimum 3 m limit of approach for pedestrians is required (refer to Appendix 6A Figure 6.7).

All materials used to fabricate a screening device must be constructed of galvanized steel and properly grounded. Screen design must consider SUI requirements.

6.4.6.6 Vibrations & Special Connection Details

Due to the vibration associated with LRT operations, the Designer must specify appropriate non-permanent thread locking compounds for all threaded fastenings. Lock washers and nuts must be specified where appropriate.

The effect of vibration fatigue must be considered in design of LRT components and concrete anchorages.

6.4.6.7 Concrete Anchors

Fittings and assemblies mounted to concrete structures must be fastened with specially designed anchors cast into the concrete or with other approved concrete anchors.

Anchorages must have adequate corrosion resistance, in wet or corrosive environments stainless steel anchors should be used. Additional anchors may be specified to provide long-term durability and an increased factor of safety. Anchorages requiring epoxy compounds or cements should only be used upon approval of the Engineer.

6.4.7 In-Span Assemblies

In-span assemblies are additional devices that are required to make the OCS functional. Guidelines for various in-span assemblies that may be included in the Design are provided below.

6.4.7.1 Dropper Wires

Dropper spacing must support the contact wire evenly throughout each span. Dropper wires must be isolated so that they do not create a conductive path between the contact and messenger wires. Droppers adjacent to supports must not contribute to creation of a hard spot.

6.4.7.2 Equalizing Jumpers

Equalizing jumpers (also known as in-span jumpers or catenary Bonds) must satisfy system electrical requirements for ampacity, voltage drop, and wire heating. Jumpers should be placed at least 2 m from any suspended equipment on the contact wire.

Additional jumpers may be required in acceleration zones. Jumper conductivity must be the same or higher than the smallest wire it is bonded to and minimum jumper size must be 336 strand 4/0 bare copper. Jumpers must not be installed at locations near section isolators or splices.[7]

6.4.7.3 Parallel Feeder Bonds

Where a parallel feeder cable or parallel messenger wire is installed along the track alignment, parallel feeder bonds must be provided between the parallel feeder and the messenger wire. The parallel feeder bonds must be spaced to meet the required ampacity, voltage drop, and wire heating limits. Parallel feeder bonds must follow DC feeder cable requirements.

6.4.7.4 Feeders

Positive feeder design must be coordinated with the design of a TPSS. To limit cable lengths, feeders must be located as close as practicable to a TPSS.

Where practicable, feeders must be located close to Stations to limit voltage drop and wire heating near acceleration zones.

NCF design must be coordinated with the Signal System design for connection to rail. This should be done at the centre tap of an impedance Bond.

6.4.7.5 Electrical Switches

Each TPSS must include Feeder Switches (one for each circuit) that provide a disconnect point between the TPSS and the OCS. Tie Switches must be provided to connect two adjacent OCS circuits together. These switches are normally open and are used to bypass a TPSS during a feeder outage

Sectionalizing switches may be required to connect two adjacent portions of a single OCS circuit. These sectionalizing switches are normally closed to improve operational flexibility and should only be used in special circumstances, such as crossovers or additional sectionalizing. Additional switches to improve flexibility of maintenance activities may be required at an OMF. Technical requirements are provided in the power distribution section of this guideline.

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[7] This type of installation can create hard spots in the system that may cause damage to the pantograph or any nearby equipment and may accelerate contact wire wear.

6.4.7.6 Section Isolators

Where two adjoining positive overhead contact wire circuits meet, a section isolator must be provided to electrically separate the circuits from each other with a level of insulation rated for the system. A Tie Switch must be installed across the section isolator to connect to the two adjacent circuits during abnormal conditions or TPSS maintenance.

Section isolators should not be installed in an LRV acceleration zone.

Section isolators must be suitable for maximum operating Train speed in both directions. They must be designed and located to prevent loss of contact with the pantograph. Section isolators must be installed as close as practicable to the pantograph static centreline.

On open Trackway, section isolators must be suspended from catenary messenger wire or other span wires. In box tunnels and underground Stations, section isolators must be suspended with dropper wires and brackets that accommodate movement of the component due to contact wire thermal expansion and contraction.

6.4.7.7 Splices

Contact wire splices are not permitted in new construction. If splices are required on contact wires, they must not be installed near any OCS support structures or section isolators where they can create hard spots. Splices must have an ampacity rating equal to or greater than the conductor, and mechanical strength equal to or higher than the wire being spliced.

6.4.7.8 Conductors and Related Devices

The OCS Designer must confirm that selected conductors possess characteristics that meet the specific system design requirements for ampacity, resistance, insulation level, and tensile strength. All electrical connections in the OCS and PDS which are current carrying under normal operating conditions must be made with bolted or compression type clamps.

6.4.7.9 Surge Protection

Surge protection devices, referred to as surge or lightning arrestors, are devices designed to divert overvoltage events to earth protecting the OCS and downstream connected equipment. Ratings of surge arrestors must be coordinated with TPSS surge protection.

Surge arrestors must be insulated from the mounting surface with minimum 25 mm stand off from any conducting surface. Surge arrestors on the LRT ROW must be provided at the following minimum locations:

- Tunnel entrances
- Open corridor feeders where underground feeder cables tap onto exposed aerial contact lines
- Midway between TPSS on an open corridor
- Any open line location of prominent height
- End of line (reflective wave prevention)
- Above ground Mainline disconnect or section isolating switch locations

Tracks must not be bonded to the surge protection ground. Surge arrestors installed in the LRT ROW may include a surge counter mounted at eye level. Design of the surge protection system must consider CSA-B72.

6.4.7.10 Structure Grounding and Bonding

The LRT TPS is an ungrounded (floating) system except for yard or shop track where tracks may be grounded. Grounding must be provided for all OCS supporting structures

Separate ground must be provided at each structure using ground rods with a maximum allowable resistance for OCS poles of 10 Ω. A separate ground must also be provided for all lightning arrestors with maximum resistance of 5 Ω. The two ground systems, OCS and surge protection must be tied together below grade where present on the same structure. In tunnel applications, a continuous OCS bonding conductor must be provided for grounding all OCS hardware. Additional details are provided in Chapter 11, Electrical Systems.

All metallic objects within 2 m of an OCS structure must be bonded to the OCS ground.

6.4.7.11 Protective Grounds

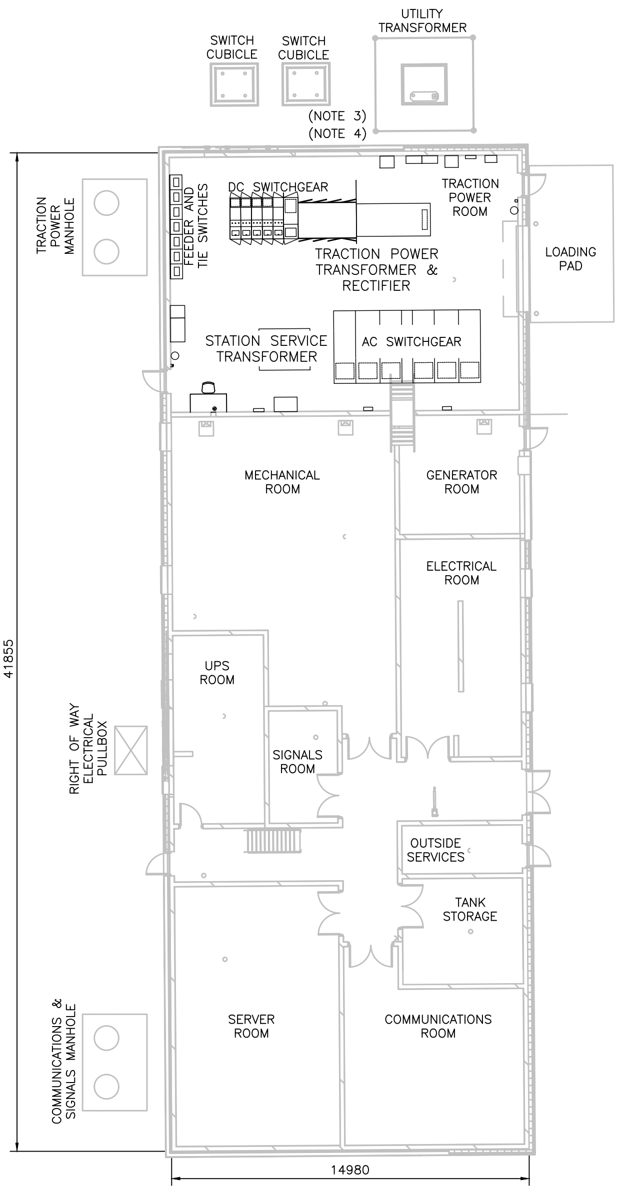
Protective Ground points, also referred to as temporary grounds, are used for grounding the OCS wires during maintenance or repairs. Protective Ground points must be installed at Feeder Switches, Tie Switches and sectionalizing switches and must be designed to conduct lightning surges and system fault current to ground.

6.5 TESTING AND COMMISSIONING

Testing and commissioning of the TPS must be carried out in accordance with an overall commissioning plan and program (refer to Chapter 1, General).

APPENDIX 6A – FIGURES

CITY OF EDMONTON LRT
DESIGN GUIDELINES

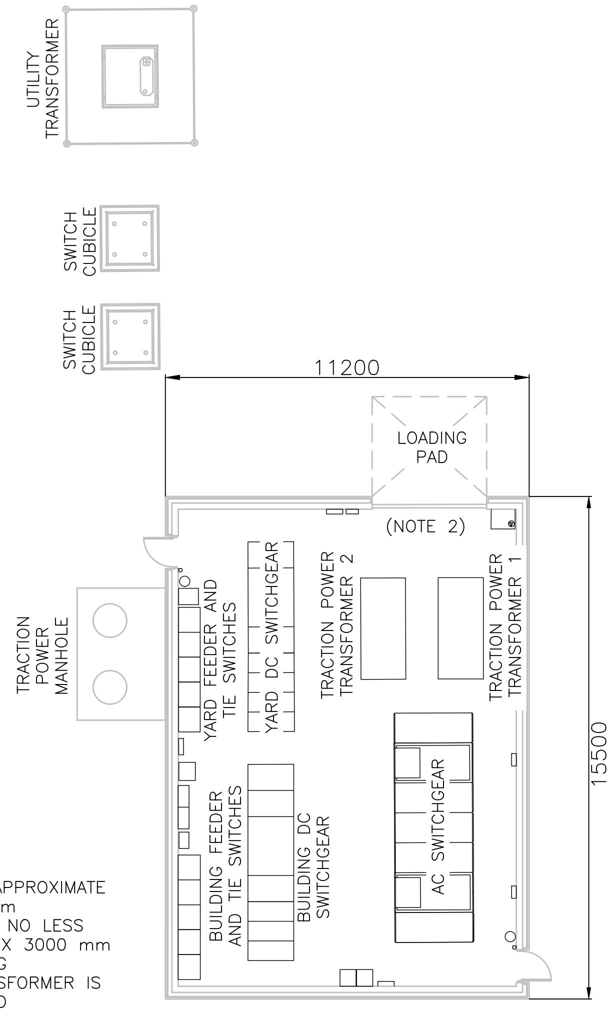


NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE AND ARE SHOWN IN mm
2. ROLL UP DOOR TO BE NO LESS THAN 3000 mm HIGH X 3000 mm WIDE FINISHED OPENING
3. STATION SERVICE TRANSFORMER FOR ALTERNATE UTILITY FEED LOCATED IN TRACTION POWER ROOM.
4. LOCATION OF UTILITY PADMOUNT STATION SERVICES TRANSFORMER, SWITCH CUBICLES, AND MANHOLES ARE TYPICAL AND FOR INFORMATION ONLY.
5. TRACTION POWER ROOM HEIGHT TO BE COORDINATED WITH FACILITY DESIGNER TO ACCOMMODATE SUPPLIER ARC RESISTANT AC SWITCHGEAR VENTING REQUIREMENTS.
6. SERVER ROOM IS SHOWN FOR INFORMATION ONLY. REQUIREMENTS FOR SPECIFIC ROOM TO BE COORDINATED WITH ENGINEER AND OWNER.

Date	Revision	FIGURE 6.1A TYPICAL UTILITY COMPLEX BUILDING LAYOUT	CHAPTER 6 TRACTION POWER

CITY OF EDMONTON LRT
DESIGN GUIDELINES



NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE AND ARE SHOWN IN mm
2. ROLL UP DOOR TO BE NO LESS THAN 3000 mm HIGH X 3000 mm WIDE FINISHED OPENING
3. STATION SERVICE TRANSFORMER IS LOCATED IN OMSF YARD
4. LOCATION OF UTILITY PADMOUNT STATION SERVICES TRANSFORMER SWITCH CUBICLES, AND MANHOLES ARE TYPICAL AND FOR INFORMATION ONLY
5. TRACTION POWER ROOM HEIGHT TO BE COORDINATED WITH FACILITY DESIGNER TO ACCOMMODATE SUPPLIER ARC RESISTANT AC SWITCHGEAR VENTING REQUIREMENTS

Date	Revision	FIGURE 6.1B	CHAPTER 6
		TYPICAL OMSF TPSS BUILDING EQUIPMENT LAYOUT	TRACTION POWER

CITY OF EDMONTON LRT
DESIGN GUIDELINES

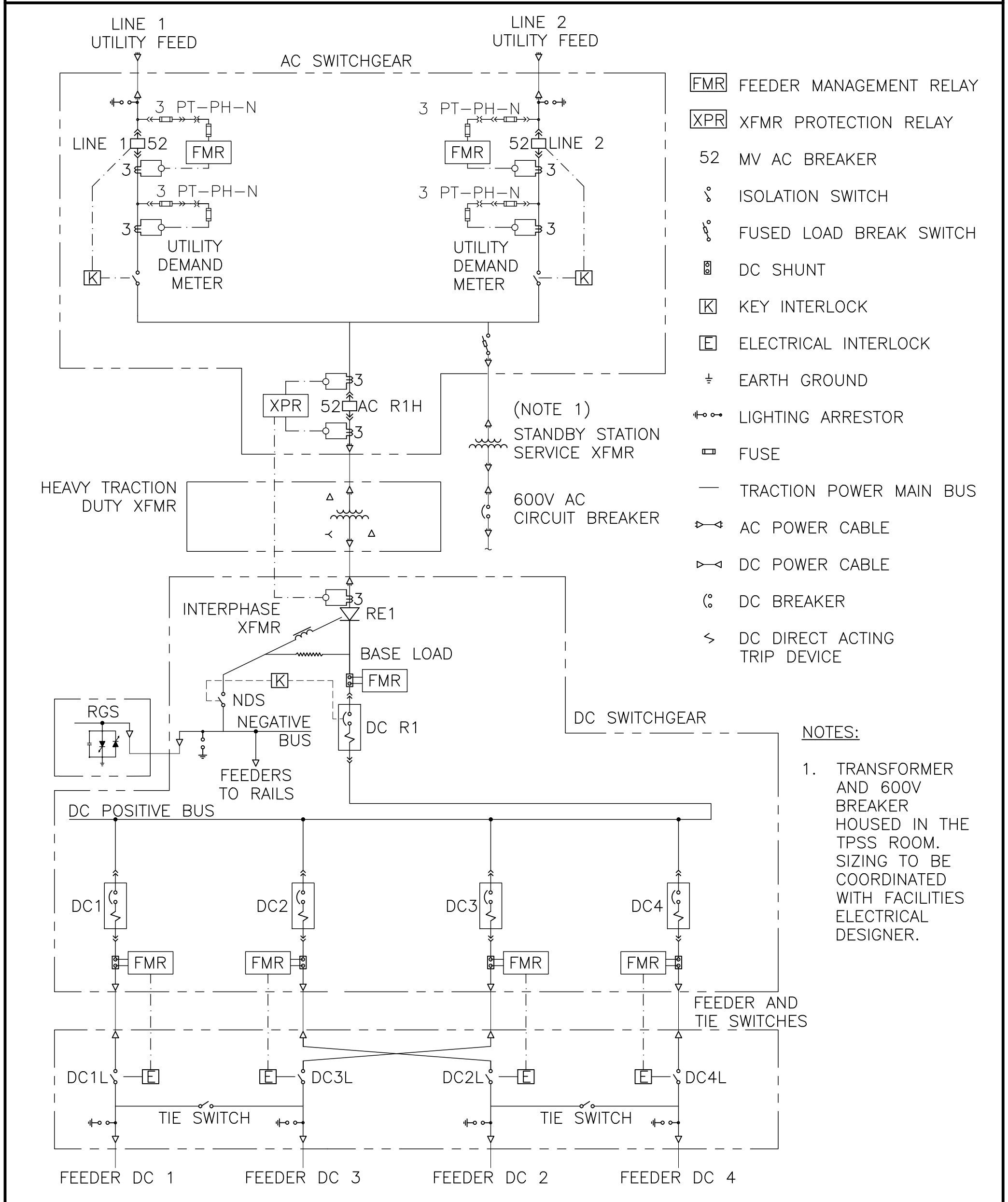
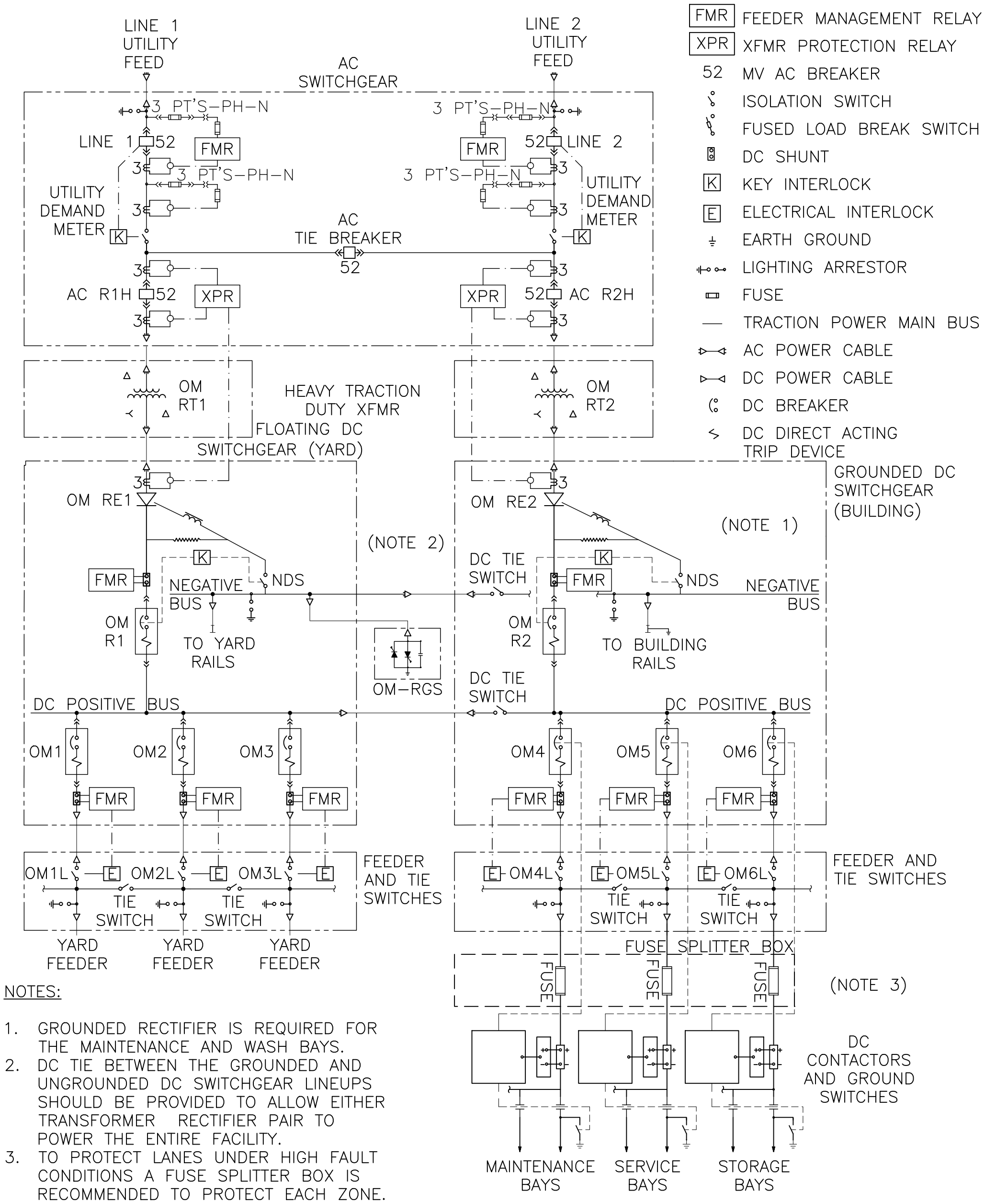


		FIGURE 6.2A TYPICAL MAINLINE TPSS SINGLE LINE DIAGRAM	CHAPTER 6
			TRACTION POWER
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES



FMR	FEEDER MANAGEMENT RELAY
XPR	XFMR PROTECTION RELAY
52	MV AC BREAKER
	ISOLATION SWITCH
	FUSED LOAD BREAK SWITCH
	DC SHUNT
K	KEY INTERLOCK
E	ELECTRICAL INTERLOCK
	EARTH GROUND
	LIGHTING ARRESTOR
	FUSE
	TRACTION POWER MAIN BUS
	AC POWER CABLE
	DC POWER CABLE
	DC BREAKER
	DC DIRECT ACTING TRIP DEVICE

NOTES:

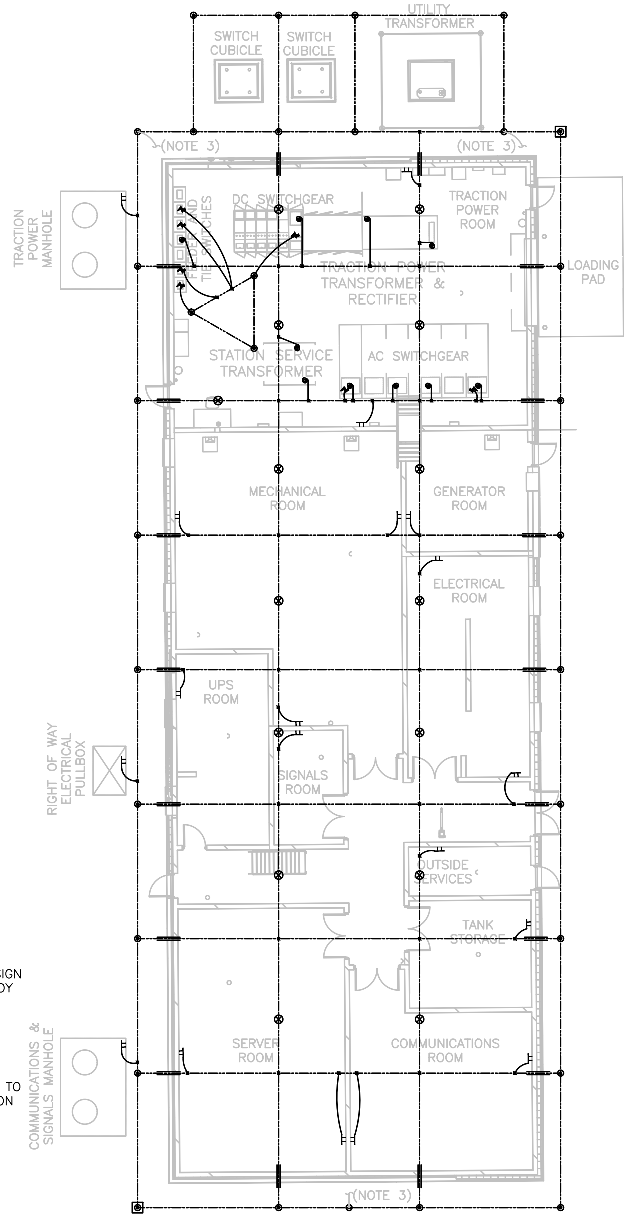
1. GROUNDED RECTIFIER IS REQUIRED FOR THE MAINTENANCE AND WASH BAYS.
2. DC TIE BETWEEN THE GROUNDED AND UNGROUNDED DC SWITCHGEAR LINEUPS SHOULD BE PROVIDED TO ALLOW EITHER TRANSFORMER RECTIFIER PAIR TO POWER THE ENTIRE FACILITY.
3. TO PROTECT LANES UNDER HIGH FAULT CONDITIONS A FUSE SPLITTER BOX IS RECOMMENDED TO PROTECT EACH ZONE.

Date	Revision	FIGURE 6.2B TYPICAL OSMF TPSS SINGLE LINE DIAGRAM	CHAPTER 6 TRACTION POWER

CITY OF EDMONTON LRT DESIGN GUIDELINES

LEGEND

- BUILDING REBAR GROUND CONNECTION
- GROUND TAIL EQUIPMENT GROUNDING
- GROUND TAIL LIGHTING ARRESTOR
- GROUND ROD
- GROUND TEST WELL
- GROUNDING BUS BAR
- MAIN GROUND GRID
- GROUND BONDING WIRE
- GROUNDING CONNECTION
- CONDUIT FOR GROUND WIRE

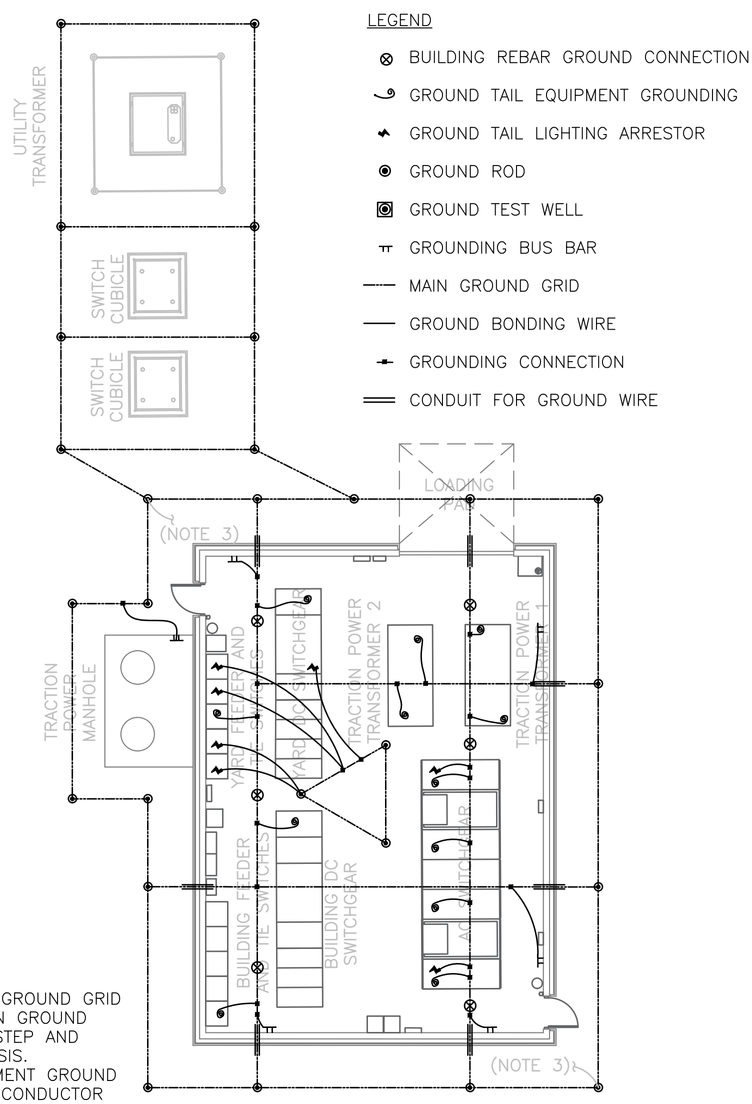


NOTES:

1. TYPICAL LAYOUT SHOWN. GROUND GRID DESIGN TO BE BASED ON GROUND RESISTIVITY STUDY AND STEP AND TOUCH POTENTIAL ANALYSIS.
2. UTILITY PROVIDER EQUIPMENT GROUND GIRD DESIGN INCLUDING CONDUCTOR SIZING AND INTERFACE WITH UTILITY COMPLEX GROUND GRID TO BE COORDINATED WITH UTILITY PROVIDER.
3. FOR CONNECTION TO ROOF LIGHTNING GRID TO BE COORDINATED WITH LIGHTNING PROTECTION DESIGNER.

Date	Revision	FIGURE 6.3A TYPICAL UTILITY COMPLEX GROUND GRID LAYOUT	CHAPTER 6 TRACTION POWER

CITY OF EDMONTON LRT
DESIGN GUIDELINES



NOTES:

1. TYPICAL LAYOUT SHOWN GROUND GRID DESIGN TO BE BASED ON GROUND RESISTIVITY STUDY AND STEP AND TOUCH POTENTIAL ANALYSIS.
2. UTILITY PROVIDER EQUIPMENT GROUND GRID DESIGN INCLUDING CONDUCTOR SIZING AND INTERFACE WITH TPSS BUILDING GROUND GRID TO BE COORDINATED WITH UTILITY PROVIDER.
3. FOR CONNECTION TO ROOF LIGHTNING GIRD TO BE COORDINATED WITH LIGHTNING PROTECTION DESIGNER.

		FIGURE 6.3B TYPICAL OMSF TPSS BUILDING GROUND GRID LAYOUT	CHAPTER 6
			TRACTION POWER
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

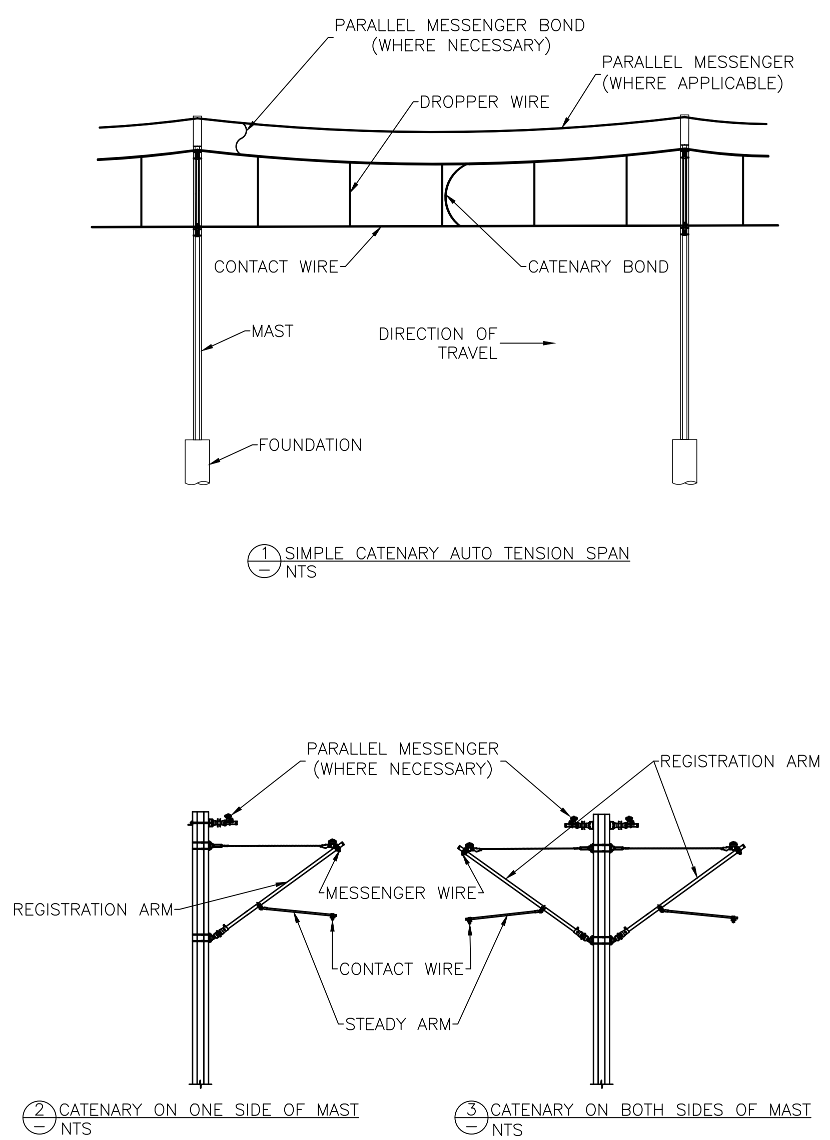
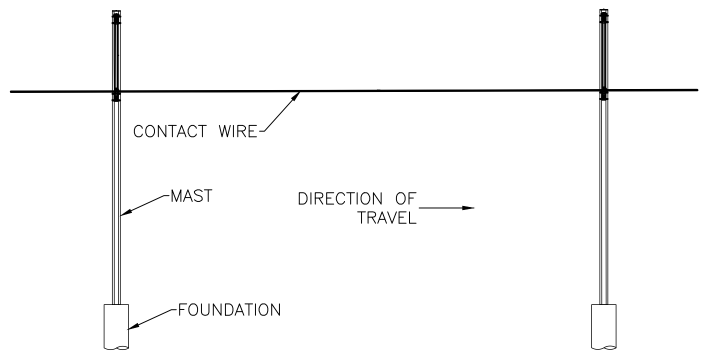
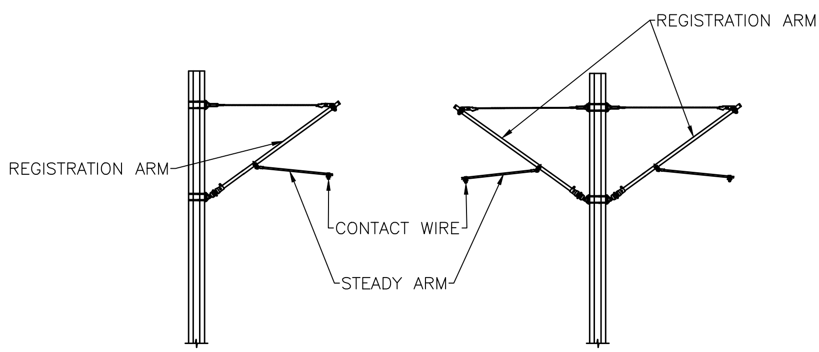


		FIGURE 6.4A	CHAPTER 6
		TYPICAL OCS	TRACTION POWER
		SIMPLE CATENARY AUTO TENSION	
		LAYOUT	
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES



1 CONTACT WIRE AUTO TENSION SPAN
NTS

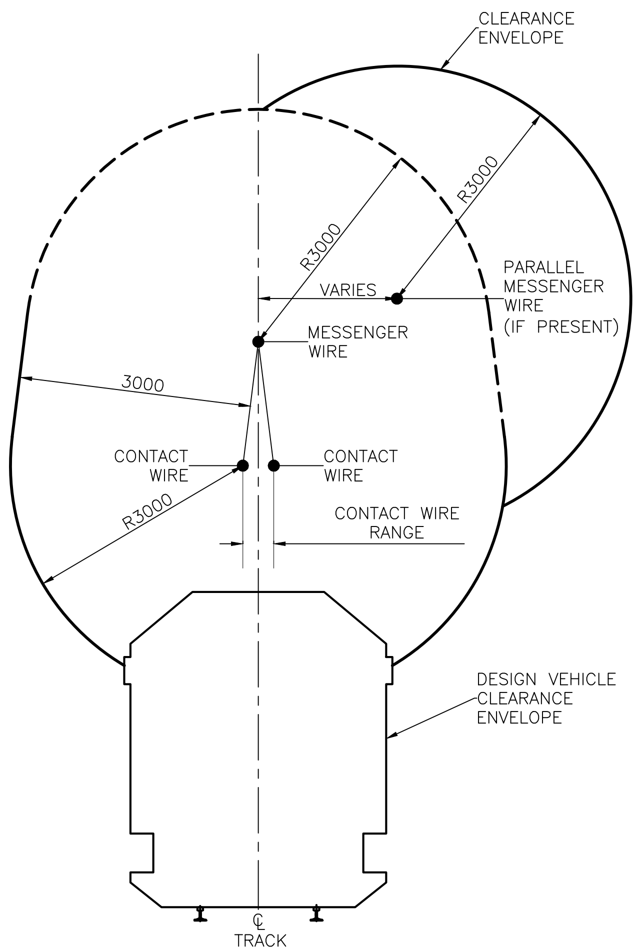


2 CATENARY ON ONE SIDE OF MAST
NTS

3 CATENARY ON BOTH SIDES OF MAST
NTS

Date	Revision	FIGURE 6.4B TYPICAL OCS CONTACT WIRE AUTO TENSION LAYOUT	CHAPTER 6 TRACTION POWER

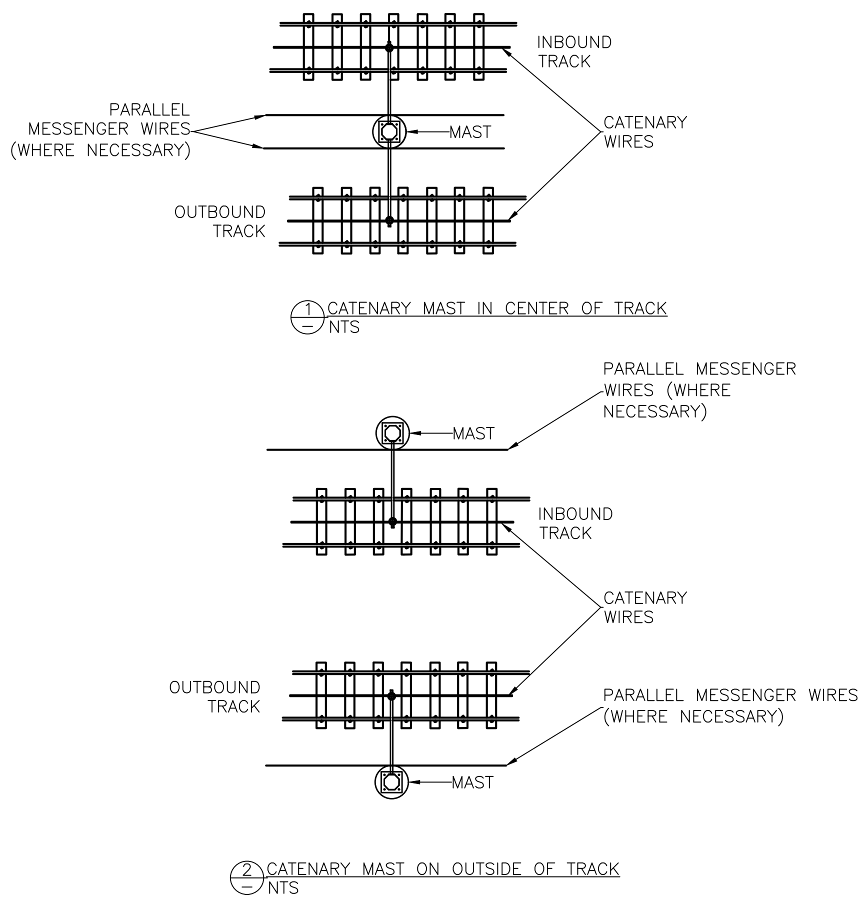
CITY OF EDMONTON LRT
DESIGN GUIDELINES



1 SIMPLE CATENARY CLEARANCE REQUIREMENTS
– NTS

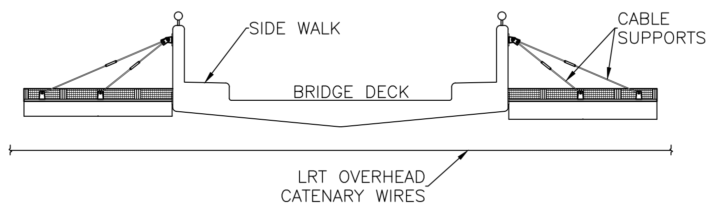
		FIGURE 6.5	CHAPTER 6
		TRACTION POWER EQUIPMENT CLEARANCE REQUIREMENTS	TRACTION POWER
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

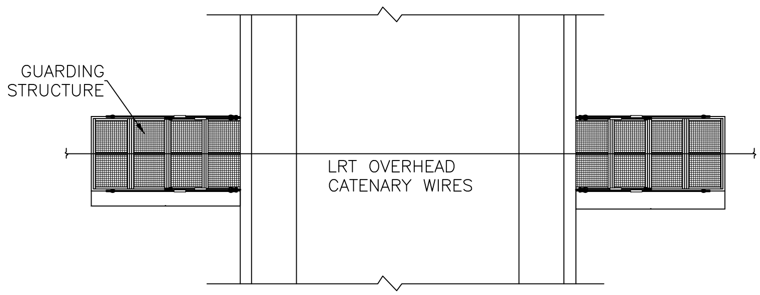


Date	Revision	FIGURE 6.6 OCS MAST PLACEMENT TYPICAL	CHAPTER 6 TRACTON POWER

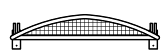
CITY OF EDMONTON LRT
DESIGN GUIDELINES



1 BRIDGE/PORTAL CATENARY WIRE PROTECTION – SECTION VIEW
NTS



2 BRIDGE/PORTAL CATENARY WIRE PROTECTION – PLAN VIEW
NTS



3 BRIDGE/PORTALCATENARY WIRE PROTECTION – PROFILE
NTS

NOTES:

1. SHROUD TO PROVIDE PROTECTION FOR ALL OCS CONDUCTORS.
2. CONFIGURATION MAY VARY.

Date	Revision	FIGURE 6.7 TYPICAL CATENARY WIRE PROTECTION BRIDGE / PORTAL STRUCTURE	CHAPTER 6 TRACTION POWER

CHAPTER 7

Signals

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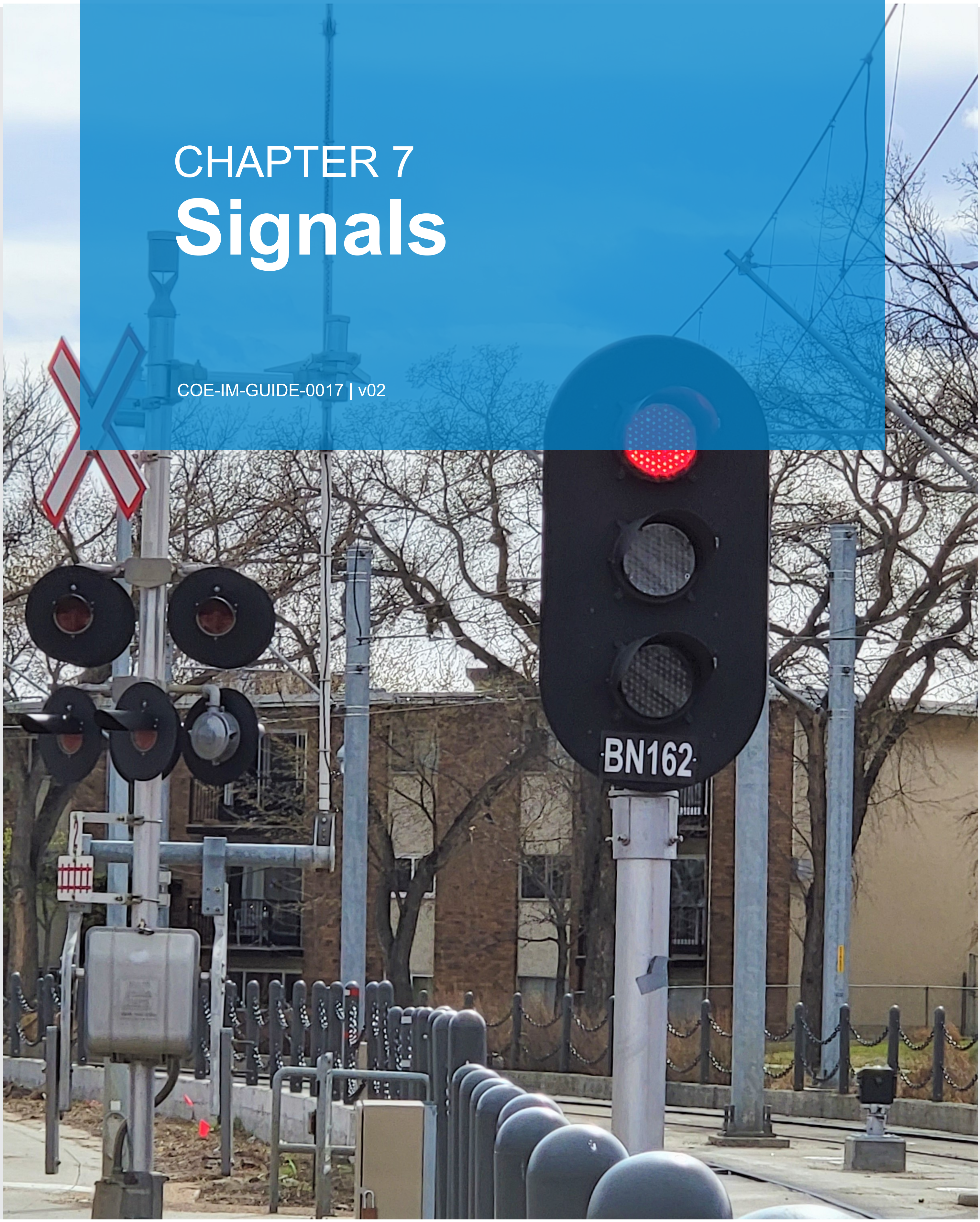

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INTENT OF USE

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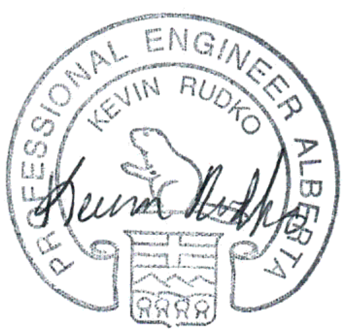


2022-MAR-29

Permit to Practice

PERMIT TO PRACTICE
SIGNALOGIC SYSTEMS INC.

Signature Kevin Rudko

Date Mar. 29 2022

PERMIT NUMBER: P 11807

The Association of Professional Engineers and Geoscientists of Alberta

7 SIGNALS

7.1 INTRODUCTION

This chapter presents guidelines and general requirements for the design of modifications and extensions for Signals on the Light Rail Transit (LRT) System and its related components.

This document does not provide detailed descriptions of individual Signal functions. For this information, refer to the latest version of the Edmonton High Floor LRT Signal Engineering Manual.

7.2 STANDARDS

All Designs, components and installation procedures must follow the applicable standards and provisions in the following documents:

- American Railway Engineering and Maintenance of Way Association (AREMA) [39]
- European Committee for Electrotechnical Standardization (CENELEC) Standards EN50126 [61], EN50128 [62] and EN50129 [63]
- Transport Canada Grade Crossing Standards [64]
- Canadian Electrical Code (and related applicable standards for Materials)
- Canadian Standards Association (CSA)

7.3 REFERENCE DOCUMENTS

- High Floor LRT Signals Engineering Manual
- AREMA Communications & Signals Manual of Recommended Practices

7.4 PERFORMANCE AND SAFETY

7.4.1 Goals and Objectives

Operation of the LRT System requires that the Signal System:

- Prevent collisions between Trains, fixed objects, and motor vehicle, cyclist, or pedestrian traffic
- Allow safe travel through Mainline turnouts with switch points set in either position
- Allow travel on either track in either direction while preventing opposing Train movements
- Automatically dispatch Trains to travel on either track according to predefined service patterns
- Provide a means to automatically dispatch Trains at a Terminus to allow for a change in direction
- Allow for provisional Terminus support at select Stations
- Allow efficient operations through intersections with roadways and shared-use facilities
- Allow LRT Controller to intervene from remote and local control centres
- Maintain service efficiency through automation of routine and repetitive tasks and functions
- Enforce operating safety rules and equipment restrictions

7.4.1.1 Direction of Running

The LRT System typically operates in a right-hand running pattern but must be designed for full bi-directional movements to maintain service during incidents or for maintenance work.

7.4.1.2 System Schedules/Headways

Mainline design speed for the LRT System is 80 km/h, although Train operating speed is restricted to a maximum of 70 km/h. Design speed for non-Mainline track is provided in Chapter 4, Track Alignment.

The LRT System Consists range in size from one to five Light Rail Vehicles (LRV).

Chapter 1, General provides the operating frequency for the LRT System. The Signal System design headway relates to peak service minimum Operational Headways as described in Table 7.1 below.

Table 7.1 Headway Design Requirements for Different Regions of the LRT System

Region	Minimum Operational Headway (minutes)	Design Headway (minutes)
All	5	2.5
All	2.5	1.5
Nearest Interlocking to Terminus (including a turnback)	All	3

The Signal System Design must support 15-minute headways in single-track operation between any two adjacent Interlockings.

Under peak headway performance, the Terminus must support a six-minute layover from the time the Train arrives in Station until the Train departs.

The difference between peak Operational Headway and Design Headways provides adequate Signal System response for Train delay recovery.

Preliminary Signal System Designs and operation plans must consider Operational Headway requirements. Operational modelling must be performed for new extensions and LRT System renewals to validate proposed Designs. Operational modelling must be based on five LRV Consists.

Intersection operations for all modes of operation must be included as part of the operational modelling.

7.4.1.3 Level of Safety

Based on the type of operation selected for an area of Mainline track, the Signal System must mitigate the operational risks presented in Table 7.2 below.

Table 7.2 Signal System Mitigation of Typical Operational Risks based on Train Priority

Risk Type	Operating Zone	
	Full Priority – Traditional Signaling	Partial Priority – Modified Train/Traffic Signaling
Following Move Collision	Yes	No
Opposing Move Collision	Yes	Yes
Conflicting Move Collision	Yes	Yes
Vehicular Collision	Provide Warning	Provide Control
Pedestrian/Cyclist Collision	Provide Warning	Provide Control
Over-Speed Derailment or Injury	Yes	Yes

7.4.1.4 Operating Assumptions and Principles

Operation of the Signal System requires that ETS personnel comply with all Signal System rules and procedures, and that Signal System failures will result in a more restrictive operational condition.

The Designer must implement a formalized process for initiating and executing system changes that enhance the safe transportation of Passengers. On large, complex projects, or where required by the Engineer, this may be accomplished through Systems Assurance (refer to the Systems Assurance Guideline for additional information). On smaller projects, this may be accomplished through a stand-alone System Safety Program. The process must include the review, updating, and publication of the following documents:

- LRT Operating Rules
- LRT Standard Operating Procedures (SOPs)
- Safety Management System

7.4.2 Reliability, Availability, Maintainability, and Safety (RAMS)

RAMS specifications must be developed for major components that have not been previously used on the LRT System. The Designer must specify Reliability, Availability and Maintainability (RAM) requirements in accordance with industry expectations. When required by the Engineer, a Systems Assurance Plan must be developed and executed to provide confidence that the required level of RAMS are achieved on the project. Situations that may require a Systems Assurance Plan include large, complex projects or extensions, or when a new sub-system is being implemented into the existing LRT System. When required, Systems Assurance Plans must be developed based on the Systems Assurance Guideline and reflect the size and complexity of the project.

7.4.3 Safety Targets

The overall LRT System must have fewer than 1 unsafe event for every $1x10^9$ Train operating hours for Train-borne equipment and fewer than 1 unsafe event for every $1x10^9$ LRT System operating hours for Wayside equipment.

7.4.4 RAM Targets

When required by the Engineer, the RAM Targets should be defined in the project specific RAM Program Plan document. Refer to the Systems Assurance Guideline for additional information on the RAM Program Plan.

7.4.5 System Safety Principles

7.4.5.1 Systems Assurance

Systems Assurance activities on a project will be governed by a project-specific Systems Assurance Plan developed in accordance with the Systems Assurance Guideline. All safety related tasks must adhere to the Systems Assurance Plan and provide an auditable trail of documentation from the design to the handover of the system.

7.4.5.2 Design

The severity of risk associated with railway operations necessitates that the Signal System outputs manifest a safe state regardless of the internal system failures that may occur. All identifiable failure-modes within a Signal System must be anticipated and, if possible, mitigated as part of the design process. A latent failure must not result in an unsafe condition when combined with any other failure. Failure modes that cannot be removed from a system through engineering mitigations must be detected through a prescribed periodic testing program of the affected subsystems to detect failures before they can cause an unsafe outcome.

The Signal System must be designed to achieve the safest operation possible while maintaining the required operational efficiency.

The Signal hardware design must be based on Vital Signal principles, specifically safety-critical engineering principles rated as SIL4 or equivalent based on the IEC 61508 standard.

Systems must be installed both on the Wayside and the LRV that will prevent the selection of conflicting routings, maintain safe Train separation and limit speeds. If any of these issues occur, these systems must bring about the enforced and non-recoverable stopping of the Train.

7.4.5.3 Checked-Redundancy Principle

The checked-redundancy principle applies to safety-critical hardware and/or software configurations, where the failure or combinations of failures in a system can result in a condition known to be unsafe. Therefore, each function of a component or subsystem which is designed in accordance with the checked-redundancy principle must provide a level of safety equivalent to that provided by the same function designed in accordance with the Failsafe principle.

Vital systems and products which cannot be built intrinsically Failsafe, such as a solid-state computer, always use a form of checked-redundancy principle within subsystems to ensure that the overall system is Failsafe.

The checked-redundant control configuration, whether it comprises hardware or software elements, must incorporate at least two parallel control units processing a common system characteristic and a means of comparing the output of the control units. If there is agreement from the comparison, then the system may be allowed to respond in accordance with the output of the control units. If there is disagreement, the system must immediately revert to a safe state.

The following characteristics, at a minimum, must be incorporated into the checked-redundancy design:

- The checking process must be inherently Failsafe
- The checking process must be sufficiently frequent that similar or identical errors or failures in redundant units could not occur between checks
- The checking process must be sufficiently sensitive to detect significant errors in a single unit
- Failure to check must cause timely action to occur which maintains safety
- Redundant units must be sufficiently independent that hazards due to common errors cannot occur
- The checking mechanism used to detect a failure and initiate a safe system reaction to the failure must not be compromised by the failure

7.5 SIGNAL SYSTEM ARCHITECTURE

The design of the Signal System must be based on the Fixed Block System (FBS) engineering design principles outlined in these Guidelines.

New Signal Systems must function identically to the existing Signal System as outlined in this document and the High Floor LRT Signals Engineering Manual. This provides consistent conditions for Train Operators (TO) across the LRT System and permits the LRT Operations Control Centre (OCC) to manage the movement of Trains regardless of the physical Signal System architecture to which information is being issued or received from.

Signal System must be of Vital design and should be based on AREMA Communications and Signals Manual of Recommended Practices, although CENELEC standards (EN 50126, 50128, and 50129) may be acceptable upon approval of the Engineer. When elements of both standards are used together, such as an interface between Vital subsystems, the interface and accepted design treatment must be documented through the Systems Assurance process.

7.5.1 Vital Train Detection

Two different types of Vital Train detection are acceptable on the LRT System:

- Track circuits
- Axle Counter Blocks (ACB)

7.5.1.1 Track Circuits

Vital track circuit systems must be compatible with Direct Current (DC) traction electrification. Refer to Chapter 6, Traction Power for compatibility requirements with Traction Power Systems (TPS).

Sequential Occupancy Restoral System

A Sequential Occupancy Restoral System (SORS) indicates that a track circuit that was occupied behind a preceding Train is not be deemed vacant unless an adjacent track circuit is occupied. SORS ensures that the Signal System will not lose the location of a Train if the Train fails to shunt a track circuit effectively.

False occupancy alarm status occurs with SORS when:

- A Train exits a detectable area such as a tail-track at Terminus
- A momentary track circuit fault causes a Failsafe occupancy state without a Train present.
- A Train which is fully occupied within a single track circuit does not effectively shunt the track-circuit energy.

Where a mix of track circuits and ACBs are employed, SORS must be used.

Track Circuit Reset

A false occupancy can be resolved through a system control sent by the Centralized Train Control (CTC) or a Local Control Panel (LCP). Any occupancies latched as a false occupy due to SORS will be released upon receipt of this control. One track circuit reset control exists per Signal territory. If multiple track circuits in one Signal territory are falsely occupied, all will be restored with the one control request.

Where ACBs are employed, failure modes exist which also require appropriate occupancy reset controls.

Loss-of-Shunt Timers

Loss-of-shunt timers ensure that momentary lapse of an axle shunt will not allow a track circuit to be declared unoccupied. Loss-of-shunt events are usually of brief duration but may allow the Signal System to initiate un-safe events. This feature must be used in conjunction with SORS to enhance safety.

- Where SORS is used on both ends of a track circuit, a 5 second loss-of-shunt time must be employed.
- Where SORS cannot be used at both ends of a track circuit, a 10 second loss-of-shunt time must be employed.

Block validation simulations must account for loss-of-shunt timers where applicable.

Loss-of-shunt timers are not required for ACBs.

7.5.1.2 Axle Counter Blocks

ACB technology must provide Vital detection of operating Trains. ACB control technology must provide features that limit the effects of public interference near roadways and axle count errors.

Axle Counter Block Reset Features

ACB controllers must provide two levels of ACB occupancy reset.

Non-Conditional Reset

Enabling a non-conditional reset will set an occupied ACB to an unoccupied state. This control must only be implemented in the field at a location that allows the TO to visually confirm that the ACB section is vacant. This level of reset must be implemented through Vital principles and circuits.

Conditional Reset

Enabling a conditional reset will set an occupied ACB to an unoccupied state only if certain predefined conditions are met. This typically includes some form of Train movement, such as a Train passing through the section at slow speed prior to the system granting an occupancy reset command.

7.5.2 Fixed Block Signaling

Each track is divided into discrete sections called Signal Blocks. Each Signal Block is comprised of one or more Vital track-circuits or ACBs. A Block Signal is located at the entrance of each Signal Block which conveys visual information to the TO on authority to enter the block. The visual information provided is the Signal Aspect.

The restrictive condition of the Block Signal is a RED aspect (stop indication). The Signal must not display a GREEN aspect (proceed indication) unless all conditions are valid to allow authority into the Signal Block including the Signal overlap being vacant. Any Train that passes the Block Signal not displaying a green aspect is stopped automatically by the trip-stop magnet associated with the Block Signal.

7.5.3 Automatic Train Protection

Automatic Train Protection (ATP) prevents human error from leading to an unsafe condition for a Train. The LRT System network uses a Discrete-point Automatic Train Protection (DATP) system. The following situations are generally protected by the DATP subsystems:

- End of authority
- Restrictive Block Signals
- Terminus
- Crossing warning supervision
- Restrictive Call-on Signals
- Overspeed detection
- Geometric speed constraints (turnouts, Stations, curves)
- Braking curve supervision

7.5.3.1 Magnetic Trip-Stop System

A magnetic trip-stop system is used to bring Trains to a controlled stop if necessary. The system is comprised of a Wayside magnetic device (trip-stop) that emits a defined magnetic field which is detectable by an onboard sensing system. This is a DATP system that enacts braking of the Train to a complete stop, if conditions warrant, at specific locations.

With this system, magnetic fields function as the Wayside-to-Train transmitting media. The permanent magnetic field generated by the device is independent of any power source. Any Train passing over a de-energized trip-stop must have its penalty braking system initiated. Control circuitry can disable the stop condition of the device by energizing the trip-stop's internal electromagnet which overwhelms the magnetic field of the permanent magnet so that the resultant magnetic field is of the opposing polarity. The Train-borne equipment allows continued passage in this condition.

Magnetic trip-stops are direction dependent. A restrictive trip-stop is permissive in the opposing direction, however a trip-stop set as permissive will create a braking penalty for Trains travelling in the opposite direction than intended.

A magnetic trip-stop is installed between the rails at Signal locations, in conjunction with a wheel detector, at a Speed Check, and at a Terminus to unconditionally stop Trains near the end of track.

Design

The magnetic trip-stop and all circuit components are based on Vital principles. However, the integrity of the onboard magnetic sensing system must be maintained to ensure the highest level of operational assurance. The trip-stop device is solid-state requiring virtually no maintenance.

7.5.3.2 Block Overlap

If a Train exceeds its Movement Authority by passing a restrictive Block Signal, the Train will be forced to stop by the associated trip-stop. The Train will travel a distance past the Signal until fully stopped. To prevent a collision with another Train, each Signal Block must include an overlap detection area into the next Signal Block which is a minimum of the worst-case stopping distance at that location. This is referred to as the block overlap. A Train must not receive authority to pass a Signal unless the entire Signal Block (and interlocking if applicable) is vacant up to the next Signal and the block overlap past the next Signal is also vacant.

The standard overlap used on the LRT System is 316 m based on level tangent track. When power switches are within a block overlap, the switches must be electrically locked prior to a Train gaining authority to enter the Signal Block. See Section 7.8.4 for more details.

7.5.3.3 Speed Checks

Over-speed protection is enabled via Speed Check devices.

Speed Checks are devices which can detect over-speed conditions at a discrete point and in a specific direction. This is accomplished by timing the duration for a Train to travel a short specific distance between a wheel-detector and a trip-stop magnet. The directional wheel detector senses the passage of the first LRV axle. This triggers a solid-state timer which energizes the magnetic trip-stop when it expires. If the Train arrives prior to the timer expiring, the Train is travelling faster than the authorized speed and the trip-stop system brings the Train to a stop.

Speed Checks are typically used in the following conditions:

- Geometric speed restrictions
- Braking curve supervision at a Terminus and at Stations near At-Grade crossings
- Divergent routes when a turnout is not detected to be in the normal position

The typical distance between a Speed Check wheel detector and magnetic trip-stop is 10 m.

Speed Check timers are Non-Vital. As a result, supervisory circuits must be added to monitor Speed Check functionality and provide an alarm if a circuit fails.

7.5.4 Existing System

The Train control Signal System is located within centralized Signal Equipment Rooms (SER) strategically located along the track ROW. Each Signal room houses Vital and Non-Vital control systems that cover a portion of the Mainline. Each Signal room is capable of operating Train movements within its territory automatically and independently of other SER.

The existing SER locations and the territory are shown in Table 7.3 below:

Table 7.3 Existing SER Locations and their Signal Territories

SER	Signal Territory	Line
Belvedere (BEL)	Clareview to 66 Street	Capital
Coliseum (COL)	66 Street to Stadium	Capital
Churchill (CHU)	Stadium to Central and North from Churchill to MacEwan	Capital (Metro shared)
Corona (COR)	Central to North Portal	Capital (Metro shared)
University (UNI)	North Portal to McKernan/Belgravia	Capital (Metro shared)
South Campus (SC)	McKernan/Belgravia to South of 60 Avenue BS734	Capital
Southgate (SGT)	South of 60 Avenue BS736 to North of 34 Avenue BS1078	Capital
Century Park (CPK)	North of 34 Avenue to Century Park	Capital
Kingsway (KNG)	North of MacEwan to NAIT	Metro

Each SER interfaces with all others and operates under a Vital FBS. These systems are operated from the LRT OCC.

7.6 TRAIN MOVEMENT AUTHORITY

7.6.1 Method of Control

The Signal System for each LRT line is divided into fixed Signal Blocks. Authority for a Train to enter a Signal Block must not be given unless travel free of conflicts can be made to the end of the Signal Block with a vacant Signal Block overlap area. A Block Signal must not display a permissive aspect unless all the following conditions have been satisfied:

- The Signal Block and Signal Block overlap are not occupied
- No opposing route into the Signal Block or associated Control Block is authorized
- Switch machines are properly lined and locked for the route to be used
- Crossing warning systems have provided sufficient warning time, where applicable

7.6.1.1 Full Traffic Control Signaling

Full traffic control Signaling provides Train separation protection including following movements within a Control Block.

7.6.1.2 Modified Traffic Control Signaling

Modified traffic control Signaling provides full Train separation protection except for following movements through Control Blocks.

7.6.2 Signal Aspects and Indications

7.6.2.1 Information to Train Operators

Train authority and supplemental information is presented to the TO via Wayside Signals. The Signals convey essential information on block occupancy, crossing warning, and route establishment at specific points.

7.6.2.2 Signal Aspect and Indications

Table 7.4 Block and Interlocking Signal Aspects and Indications

Aspect	Indication	Definition
G	Clear	Proceed
FG	Clear, Traffic Fault	Proceed, approaching crossing with caution
G/L	Divergent Route, Clear	Proceed, slowing to prescribed speed through turnouts
FG/L	Divergent Route, Clear, Traffic Fault	Proceed, slowing to prescribed speed through turnouts and approaching crossing with caution
Y	Crossing Not Activated	Authority is valid, crossing ahead not yet activated
Y/L	Diverging Route, Crossing Not Activated	Authority for divergent route is valid, crossing ahead not yet activated
R/FY	Prepare to Depart	Lock doors and prepare to depart. Permissive aspect will be displayed shortly
R/Y	Hold in Station	Traffic Signal System requires additional time. Train held
FR	Restricting	Proceed at restricted speed
R	Stop	Stop

Table 7.5 Call-On Signal Aspects and Indications

Aspect	Indication	Meaning
G	Crossing Activated.	Crossing warning system is active
FG	Crossing Active, Traffic Unhealthy	Approach crossing with caution.
Y	Crossing Not Activated	Crossing not activated

7.6.2.3 Light Out Conditions

All Signals should be designed to incorporate light out detection of all lamps including dark aspects. Where lamps are not able to show their aspect colour the system must detect this fault. The following tables outline the resulting Signal aspect downgrades when a light-out condition occurs.

Table 7.6 Block Signal Light-Out Downgrades

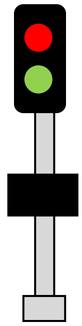
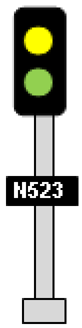
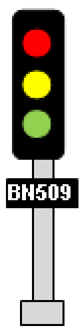
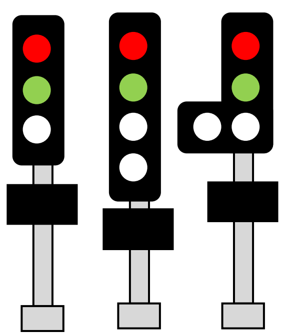
Intended Aspect	Lamp with Light-out Condition	Resulting Aspect
R	R	Dark
FR	R	Dark
Y	G	R
Y	Y	R
Y	R	Y
G	G	R
G	Y	G
G	R	G
Y/L	G	R
Y/L	Y	R
Y/L	L	R
Y/L	R	Y/L
G/L	G	R
G/L	Y	G/L
G/L	L	R
G/L	R	G/L

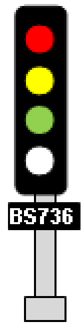
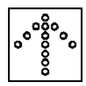
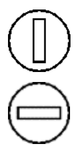
Table 7.7 Call-On Signal Light-Out Downgrades

Intended Aspect	Lamp with Light-out Condition	Resulting Aspect
Y	Y	Dark
FG	Y	FG
FG	G	Y
G	G	Y
G	Y	G

7.6.2.4 Signal Configurations

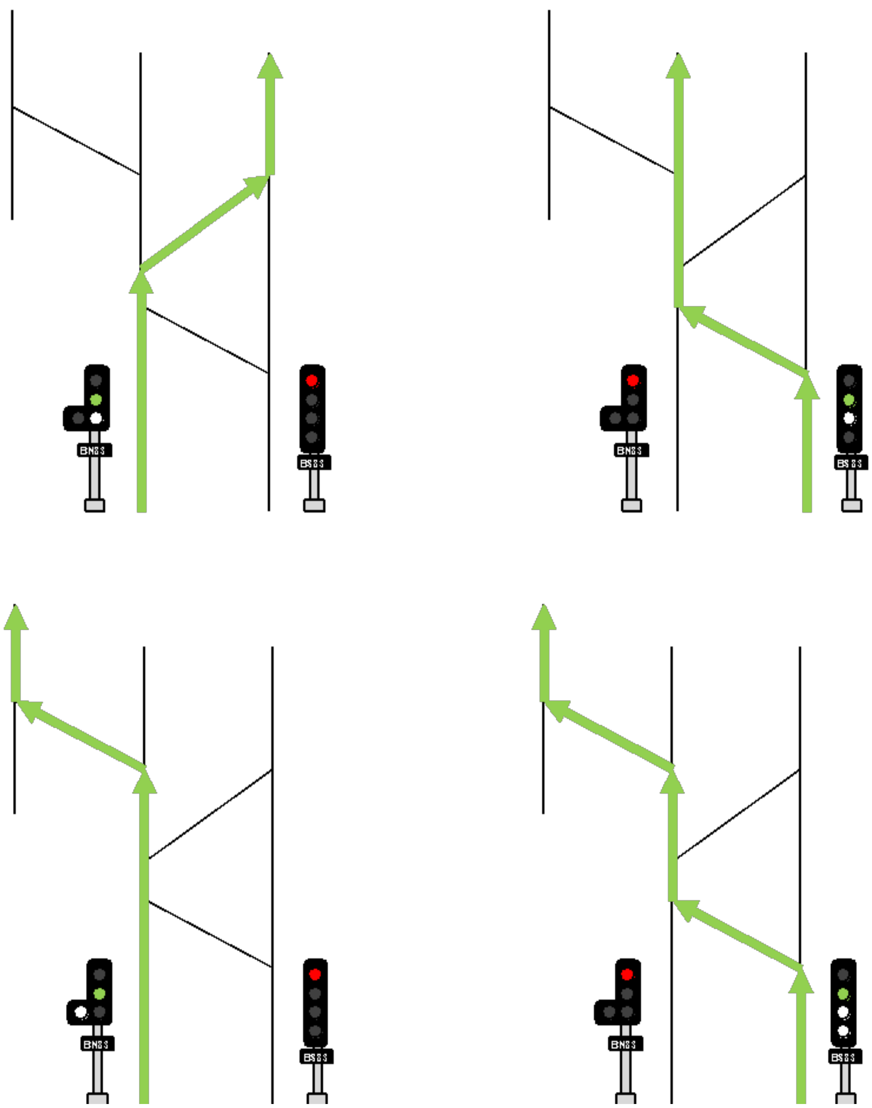
Table 7.8 Signal Configurations

Block Signal (2 aspect)		A fixed Signal at the entrance of a block/interlocking to govern Train authority. Only one aspect visible at a time.
Call-On Signal (2 aspect)		A fixed Signal used to indicate that the crossing warning system ahead of the Train has been initiated. Only one aspect visible at a time.
Combined Block/Call-On Signal		The red aspect indicates no block/interlocking authority, the yellow indicates crossing warning system not activated if authority is valid. Green is displayed if block authority is valid and crossing warning system is active. Only one aspect visible at a time.
Block Signal With Lunar		A white (lunar) aspect placed on the bottom position(s) of the Signal provides status of the track facing point switches. A lunar aspect in conjunction with a green indicates that the routing authority includes a divergent turnout. If the lunar is offset from the rest of the Signal, this denotes the direction of the route. An inline lunar typically denotes a divergent route to the other Mainline track. One or more lunar can be display with a green.

Combined Block/Call-On Signal With Lunar		Same as above, with additional information for crossing warning systems. A lunar aspect in conjunction with a yellow indicates that the routing authority includes a divergent turnout, but one or more associated crossing warning systems are not activated. One or more lunar can be displayed with a green or yellow.
Switch Position Indicator		Fixed Signals placed adjacent to switches to indicate position of the facing point switch. Vertical arrow or bar indicates normal movement.
LRT Traffic Signal		Fixed Signals at intersections driven by the traffic signal controller in MTCS territory. White vertical bar indicates movement through the intersection is permitted. White horizontal bar indicates movement through the intersection is prohibited.

7.6.2.5 Routing Scenario Aspects

Figure 7.3 Diagram of Various Routing Aspects



7.7 BLOCK DESIGN CRITERIA

7.7.1 Signal Block

Each track is divided into discrete sections called Signal Blocks. Each Signal Block must be equipped with Vital Failsafe Train detection devices that sense and indicate the presence of a vehicle within the block. A Block Signal is located at the entrance of each Signal Block.

7.7.2 Determination of Signal Block Boundary

Signal Block boundary locations may differ for each direction within the same Control Block. Signal Block boundary locations are determined as follows:

7.7.2.1 Platforms
Trains leaving a Platform must face the entrance to the next Signal Block.

7.7.2.2 Interlocking Boundaries
Where an Interlocking boundary exists, an Interlocking Signal must govern Train authority within the associated Interlocking and the Signal Block leading away from the Interlocking.

7.7.2.3 Intermediate Blocks
If a Signal Block is too long to support the desired headways, the distance may be broken into smaller Signal Blocks. Traffic Locking will allow Trains to follow each other between Interlockings but will prevent opposing movements.

7.7.2.4 Signal Sight Lines
Due to the use of a two-aspect Signal System, Trains require adequate sight lines to a Signal to allow the Train to safely stop after observing a restrictive Signal aspect.

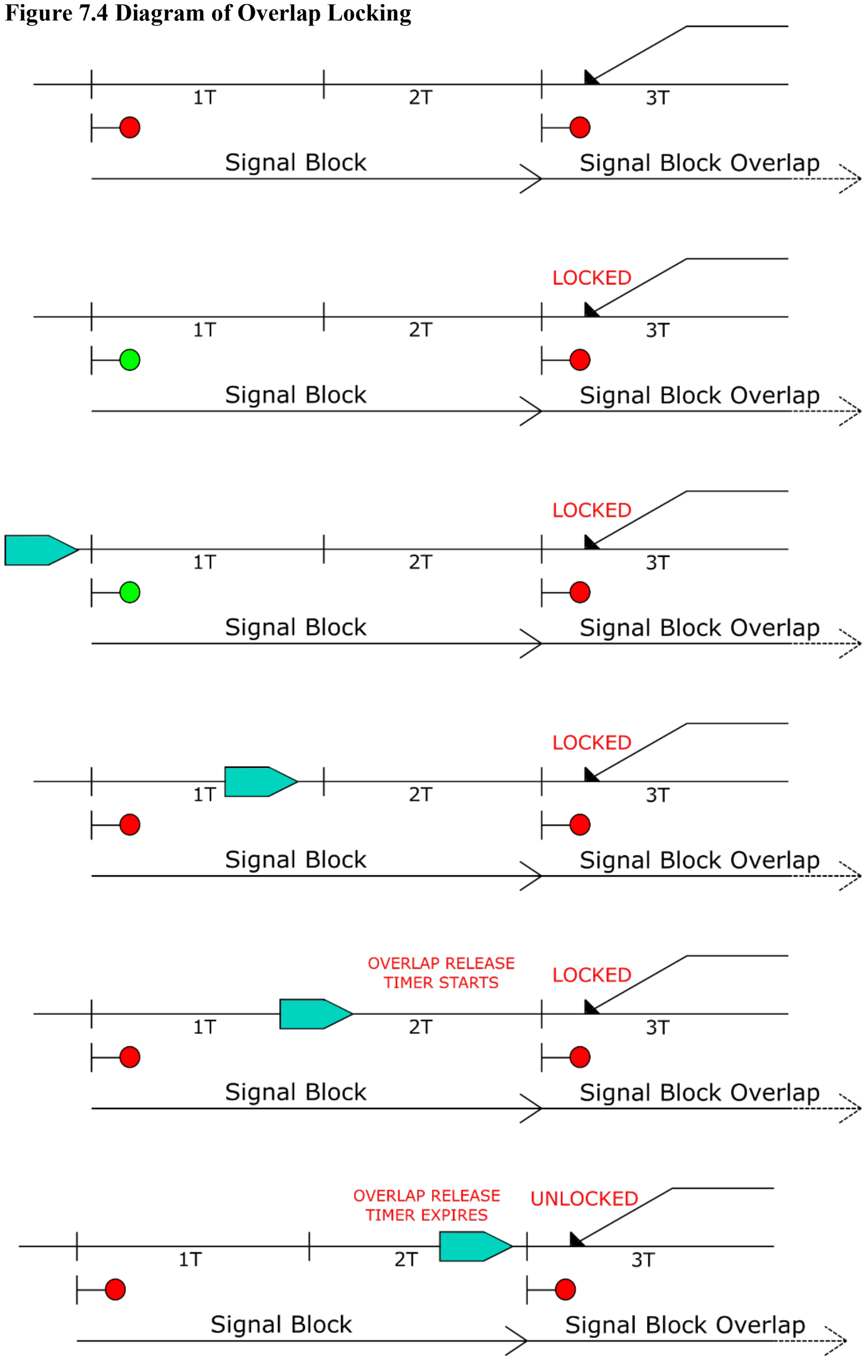
7.7.3 Signal Block Overlap
Authority to enter a Signal Block requires that the Signal Block is vacant as well as a distance into the next Signal Block and/or Interlocking defined by the worst-case stopping distance. This additional distance is called the Signal Block overlap.

7.7.4 Overlap Locking
In addition to the standard Signal Block, a Train must not receive a permissive Block Signal aspect until all conditions are also favorable for an additional distance. This accounts for a Train's braking distance if it violates the end of its authority at a restrictive Signal. The Train brakes must be automatically activated and cause the Train to come to a controlled stop. The block overlap length is derived from the worst-case stopping distance, factoring in maximum speed, maximum weight, and worst-case braking rates. The most conservative block overlap length used in Edmonton is 316 m. However, shorter block overlaps have been accepted by the Operator in areas where Station spacings are close and speeds are limited. Reduced overlap distances, where appropriate, may be used to improve operational performance.

Where an overlap contains power switches, these must be electrically locked before a Signal may display a permissive aspect into the block in advance of the overlap. This is known as overlap locking. Overlap locking can also take the form of a valid route requested through the Interlocking that contains the special trackwork.

Overlap locking is activated when the Signal associated with the overlap requests to clear. The locking remains in effect while the Train occupies the block. When the Train occupies the last track circuit in the block, a timer unlocks the switches based on the travel time within this last track circuit.

Figure 7.4 Diagram of Overlap Locking



7.7.5 Block Validation

The Designer must perform an analysis to confirm that the overall Signal Block design will support the operational requirements provided in Chapter 1, General. Intersection influences must be included in this analysis.

7.8 SPEED ENFORCEMENT

7.8.1 Speed Restrictions

Speed enforcement devices (Speed Checks) must be included in the Design to prevent a specified maximum speed from being exceeded. Enforcement devices must be applied to minimize the consequences of errors or violations of operating procedures.

7.8.2 Speed Checks

7.8.2.1 Speed Enforcement for Mainline

The speed restriction must be set to the engineered maximum speed plus an additional 5 km/h.

7.8.2.2 Placement of Speed Checks

Speed Checks Entering a Curve

Speed Checks must be placed at locations where TO error by exceeding posted speeds will result in a situation that is unsafe or a situation that exceeds Passenger comfort criteria. Speed Checks must be located in the approach to a curve, to ensure the TO can slow the Train to the Passenger comfort speed prior to entering the curve. For long curves, where it is possible for the TO to speed up while in the curve and exceed the calculated Passenger comfort speed, additional Speed Checks must be placed within the curve.

Speed Checks Entering a Station

Speed Checks are not required when approaching a Station unless there is a specific hazard. Situations where Speed Checks are required entering a Station are discussed below.

A Terminus must have a Speed Check at both tracks to prevent a collision with the end-of-line track barrier installed past the end of the Station. To add to this protection, a second Speed Check must be placed at mid-Platform and a permanent magnet installed past the edge of the Station to stop any Train from proceeding beyond the edge of the Platform.

If the Signal Block beyond the Station is shorter that the calculated braking distance, a Speed Check must be provided approaching the signal. Refer to the High Floor LRT Signals Engineering Manual for more information.

Speed Checks Approaching a Divergent Route

A Speed Check at the entrance to a crossover is required to confirm that appropriate Passenger comfort speed has been reached if the switch is lined for the reverse position. The Designer must confirm that a single speed check in advance of the crossover will both satisfy the normal braking curve to reach the divergent speed without initiating train braking as well as allow for braking to be applied to an appropriate Passenger comfort speed during an over-speed event. Where a single speed check cannot satisfy these conditions multiple speed checks must be employed.

7.8.2.3 Speed Enforcement for Stations with Adjacent At-Grade Crossings

Speed Checks must be placed at both the entrance and the centre of all Platforms with adjacent At-Grade crossings to provide monitoring that the Train is decelerating appropriately and in accordance with the proximity of the At-Grade crossing.

7.9 STANDARD OPERATIONAL FEATURES

The LRT Signal System includes the standard operational functionality available on any Interlocking based railway Signal System, including the following functions:

- Requesting a Signal/route
- Canceling a Signal/route
- Throwing a switch
- Applying blocking to field elements (Signals, track sections, blocks)

The following section highlights these functions as well as other functions present in the LRT System that may not be included in Interlocking Signal Systems used elsewhere.

7.9.1 Route Request

For the LRT System, routes are requested directly in accordance with German style railway Signaling. A single request to the Signal System is made for the route desired. If conditions allow the route, the Signal System will throw any switches required for the route. Once all the required switches indicate that they are in the correct position, the system then internally requests Signal locking to initiate the route and traffic locking in accordance with North American Signaling principles.

7.9.2 Route Cancel

The Route cancel function is associated with the originating Signal. There is only one request for each Signal which will allow a TO to cancel any route that is associated with that Signal.

7.9.3 Signal Blocking

Signal Blocking is used to keep a Signal displaying either a Stop (Red) or 'Crossing warning system not Activated' (Yellow) indication.

Signal Blocking may be applied at any time. When an Interlocking Signal is blocked, the Signal is automatically cancelled allowing the Signal to unlock, cancelling any route originating at the Signal.

7.9.4 Track Blocking

Track blocking prevents Signal authority into a Control Block. When a section of track is blocked, the automatic routing feature of the Signal System must not line routes into the blocked section of track but must automatically route Trains around the blocked section.

7.10 INTERLOCKING REQUIREMENTS

7.10.1 Interlocking

The LRT Signal System consists of the following main components:

- Vital logic control system
- Train traffic and Wayside Signals
- A Non-Vital system for Train movement display, Wayside equipment status display and command request during manual operation
- A communication system that interconnects the Vital and Non-Vital system to allow integrated functionality

7.10.1.1 Vital System

The current Vital computerized control system consists of an ElectroLogIXS Vital Logic Controller (VLC) microprocessor with both Vital and Non-Vital processing capability. Vital input/output (I/O) cards must be used for driving Signals and switch machines while Non-Vital communications and protocols provide an interface to the CTC system. Power for the total system must be backed-up by Uninterruptable Power Supply (UPS) and generator backup power.

The Vital computerized control system communicates with the adjacent SERs to exchange Vital block information. This communication must be a fully redundant network. The communication between territories must be considered an integral part of the Vital system.

7.10.1.2 Non-Vital System

The CTC system is classified as a Non-Vital system because it does not have the capability to directly control Wayside equipment. The Vital logic system directly controls the Wayside equipment. However, when the Vital logic system in the SER requires human intervention, the CTC system must be able to put the territorial Vital logic system in manual operating mode. The LRT Controller must be able to send command requests to the territorial Vital logic control system for execution. The Vital control system must confirm that any controls received provide only safe results. Refer to Section 7.5.4 for additional details.

7.10.1.3 Train Routing

A route is a combination of powered track switches, track, and field devices that allows a Train to pass through a switching area according to the designated Signal System design.

A route is established when the switches are lined and locked and all conflicting traffic is prevented from violating the route. Normally, a route path must start from the block entrance, through the next Block Signal into the overlap block. It must end at the end of the overlap block in the direction of current traffic.

7.10.1.4 Switch Position

The actual switch position must be reported via Vital circuits to the territory VLC to determine whether the requested route is safely lined for the route to be used.

Power operated switches must not indicate position until mechanical locking is achieved. Once the track switches are lined and locked (mechanically and electrically) in the proper position for the route to be used, then a route will be granted.

7.10.1.5 Interlocking

Conflicting routes must not be allowed into a section of track at any time. The Block Signal must display GREEN once a route is confirmed. However, before the GREEN indication can be displayed, the following conditions must be satisfied:

- Tracks within the block and overlap block are not occupied
- The Train is traveling in the correct direction
- The next Block Signal is operating properly and no Signal lamp element is burned out
- There is no conflicting route into the Signal Block
- Track switches are properly lined and locked for the route both electrically and mechanically
- Crossing warning systems have provided sufficient warning time, where applicable

7.10.1.6 Sectional Release on Interlocking

The release point of all switches in the Interlocking must occur after a Train vacates the last detector circuit (switch track circuit) in the route, unless this point is foul of conflicting movements. In the latter case, vacating the next track circuit (first track circuit after the switch) must be used as the release point.

7.10.1.7 Signal Relays
All relays installed in the LRT Signal System must be Vital relays, accepted for use in a railway Signal System as recognized by either AREMA or CENELEC standards.

7.10.1.8 Microprocessors
A microprocessor-based Interlocking system installed in the LRT Signal System must be compliant for use in a railway Signal System under AREMA or CENELEC standards.

7.10.1.9 Timers
All timers installed in the LRT Signal System must be accepted for use in a railway Signal System as recognized by either AREMA or CENELEC standards.

Mechanical timer relays must not be used.

Timer Applications

The LRT System permits the use of hardware timers for Speed Checks. Vital software timers must be used for the following applications:

- Signal time locking
- Overlap locking release
- Delayed reaction in crossing approaches, extended approaches and pre-emption approaches in situations where the boundary of a track circuit or ACB is not at a location that would provide an adequate approach time
- Delayed switch throw
- Gate descent delay

7.10.1.10 Centralized Train Control Connection to Signal Rooms
A Signal room VLC transmits information between the Signal territory and the CTC system at the LRT OCC.

7.10.1.11 Local Control Panels
All Signal rooms must have a LCP installed which permits either the LRT Controller or technicians located in the Signal room to monitor the Signal System status or issue operational controls to equipment within the Signaling territory controlled by the Signal room.

Display Requirements

The LCP must provide clear visual system status information within the Signaling territory, including:

- Automatic routing system status (automatic or manual)
- Status of local control (remote or local)
- Status of all track detection sections (track circuits or ACB)
- Status of all Signals (aspects, requests, timing, and light-out)
- Current position and locking status of each switch
- Status of track section, Signal and switch blocking
- Indication of any routes that have been lined
- Status of crossing warning systems
- Status of traffic light preemption
- Status of knife switches for each track at each crossing

Functional Requirements

The LCP must permit both the LRT Controller or a technician located in the Signal room to issue all operational requests accepted by the Signal System, including:

- Line a route
- Cancel a route
- Throw a switch to normal/reverse
- Set/remove a track block
- Set/remove a Signal Block
- Set/remove a switch block
- Set/remove Station turn-backs

Computer Based Local Control Panels

LCPs must be micro-processor based and use a display screen.

7.10.1.12 Event Recorders

Wayside Signaling controllers must employ data recording functionality. All logs must be in a format acceptable to the Operator.

Timing and Resolution

All events that are logged by event recorders must be time stamped to a resolution of 1 s. Event recorders memory must hold all data collected over a period of 90 days.

Events Recorded

The event logger must record changes to:

- Signal changing to green
- Signal changing to red/yellow
- Signal light out status change
- Route status change
- Signal locking status change
- Track circuit occupancy status change
- Switch position status change
- Switch lock status change
- Track block status change
- Signal Block status change
- Crossing warning system activation status change
- Crossing warning system knife switch status change
- System automatic routing mode status change

7.10.1.13 Automatic Route Cancellation

After a Train passes an Interlocking Signal, the request for the route is removed. Route Locking will enforce the route until after the Train has vacated the route. Where sectional release of the Interlocking is provided, segments of the route must be released behind the Train for subsequent route implementation.

7.10.1.14 Manual Route Cancellation

Once a route has been established, the route may be cancelled using either the CTC system or a LCP in the Signal room. A route can be cancelled at any time until a Train has accepted the route and passed the green Signal. Time Locking of the Signal will be in effect for a duration based on site specific conditions.

7.10.1.15 Bi-Directional Routing

The Signal System uses bi-directional running over the existing line. Block Signals are installed for all Train movements against the normal direction of traffic.

7.10.1.16 Automatic Routing

All routes available in the LRT System through electrically controlled crossovers can be lined automatically by the Signal System. Routes are initiated automatically by Trains occupying call-on track circuits or by wheel detectors installed on Mainline. Routes can be lined manually by the LRT Controller or by using the LCP in the Signal room, but manual intervention is not required to line any route when the system is operating in automatic mode.

7.11 AUTO-ROUTING REQUIREMENTS

7.11.1 Field Based Route Selection

The current Signal System uses a field-based automatic dispatching system to route Trains along the system. This system is integrated with the Non-Vital Application Logic embedded with the Wayside Signal System providing automated monitoring of Trains and subsequent routing according to simple operating rules.

Normal operation of the LRT System requires Trains to operate in a south direction on the southbound track and in a north direction on the northbound track. As Trains reach each Interlocking location, the system ensures that the Train has vacant track ahead and aligns a route to allow the Train to continue. When Trains arrive at a Terminus, the automatic system takes measures to have the Train resume operation in the opposite direction. When the Train is ready to depart, the automatic system routes the Train to the appropriate track and continues the process in the other direction.

7.11.2 Automatic Dispatching Rules

Normal operation on the LRT System is to run Trains in a right-hand running pattern. The automatic routing system ensures that Trains maintain this preferential pattern. When both tracks are available for use, the Train will be routed to the right-hand track.

Track blocking allows the LRT Controller or a technician at the Signal territory LCP to take a section of track out of service. Vital logic will not allow Signals to clear into blocked sections of track. The physical limits of a track block are all track between Interlockings.

The automatic routing system is responsible for routing Trains around sections of blocked track. If a blocked section of track does not allow a Train to run in the right-hand pattern, then the automatic system must determine if the Train can be routed around the section of blocked track.

The system must confirm that a valid exit location exists for the Train. To do so, the system automatically checks all tracks between the Train and the exiting point of the blocked section. If multiple sections are blocked, then the automatic system will check all track until a valid exit point is found. If a valid vacant track to the exit point is found for the Train, the Train will be allowed to continue.

When the last Signal in the single-track section is determined for all territories from Corona to Belvedere, a request will be initiated to line a route out of the blocked section into the vacant track. If successful, the Signal in advance will be requested. This process continues until the system reaches the first Signal in advance of the Train.

7.11.3 Turn-Back Mode

At a Terminus, the system must always provide turn-back functionality. There is no exit option for a Train at a Terminus other than to turn around and travel in the other direction. Under certain circumstances, it may be required to allow other Stations to function as a turn-back location. In either case, when the automatic system recognizes a Terminus, the preferred route for Trains arriving at this Station is to cross to the other track before arriving at the Station. If there are no Trains currently at the Station, an arriving Train will be crossed over to the other track prior to reaching the Terminus. If a Train is currently in one of the two tracks at the Terminus, the next Train will be routed onto the other track.

Two different types of turn-back operation must be considered at Stations from Corona to Belvedere and Metro Line territories: full turn-back and stub turn-back modes. Unique controls, accessible from the LRT OCC and the Signal territory LCPs, provide turn-back control for both modes to the automatic routing system. From University territory to Century Park territory, track blocking is used to control turn-back mode.

Full turn-back mode allows a Station to become a temporary Terminus. Trains are automatically routed back in the direction opposite of their arrival.

Stub turn-back mode is designed to allow more flexibility for operations. Stub turn-back mode allows a Station to become a transfer point by allowing Trains to enter the Station from both directions onto predefined tracks. Trains are automatically routed back in the direction opposite of their arrival. The automatic routing system initiates a turn-back route only once the Train is ready to depart the Station. This is accomplished using directional wheel detectors positioned at the Platform to detect the motion of a departing Train.

7.11.4 Route Destinations

At Interlockings such as Churchill Junction and Health Sciences where a single line branches into two, the auto-routing system must know the destination of the Train before automatic routing can occur. The LRT OCC must send a control bit that provides the auto-routing system the destination of the next approaching Train. The LRT OCC must provide this information in a timely manner so that auto-routing will occur smoothly, particularly when single-track operations are in place immediately prior to the transition.

7.12 CENTRALIZED TRAIN CONTROL

7.12.1 Basis of Operation

The CTC system is typical of the general class of Train control systems currently being installed by transit authorities in North America. It carries out data acquisition, processing, monitoring, control, presentation, and archiving functions for Train system data received from VLCs. It includes field control and indication, alarming, Train routing, and Train tracking, as well as processing of Train and crew data. Functions also exist for information storage and retrieval, playback of rail operations, and simulation of rail operations. The CTC system includes report generation functions, provides extensive user interface displays of the LRT System, feeds Train movement information to Public Address/Variable Message Sign (PA/VMS) system, and is a repository of online documentation.

7.12.2 Connectivity with Field

System servers and user workstations are connected via redundant Ethernet LAN. The system is distributed over several LRT facilities with file servers located at the D.L. MacDonald (DLM) OMF and multiple user workstations located at the LRT OCC and other key office locations. VLCs in each Signal room communicate with CTC via the industry standard Genisys protocol.

7.12.2.1 Network Infrastructure

The CTC system must be distributed over several LRT facilities using a redundant network.

The existing CTC servers are located at the University Server Room and the DLM server room. Network connectivity must be provided between these servers, the OCC equipment, the PA/VMS system servers, and the Signal room field equipment.

7.12.2.2 Communication Requirements for LRT Control

Network communications are used to transmit Non-Vital status information and controls to and from the LRT OCC.

Any additions to or modifications of the CTC system must include coordination with the CTC contractor to determine network hardware and configuration requirements. Chapter 8, Communications provides guidance on these and other related communications systems.

7.12.3 Power Requirements

All servers, control stations, VLCs, and communication network equipment are powered through an UPS attached to emergency power. Refer to Chapter 11, Electrical for requirements.

7.12.4 System Configuration

The CTC software product is based on the ARINC Advanced Information Management (AIM) platform. As configured for the CTC system, the AIM application software components include the following functions:

- Communication processing (data acquisition)
- System processing (data processing and calculations, control processing, centralized traffic control, Train tracking, Train routing, Train scheduling, event and alarm processing, data recording/archiving/playback)
- Display processing (console management)
- Maintenance processing (graphic editor, dialog editor, database and display linking, database management, simulation, configuration tools)
- Management processing (forms and reports)
- User processing (graphical user interface)

7.12.5 User Interface

7.12.5.1 Control Functions

The CTC control console must enable the LRT Controller to issue all operational requests accepted by the Signal System, including:

- Turn CTC for a Signaling territory on or off
- Put the system in automatic or manual mode for a Signaling territory
- Line or cancel a route
- Throw a switch to reverse or normal
- Reset track circuits or ACBs
- Block and unblock a track
- Block and unblock a Signal
- Block and unblock a switch
- Turn switch blowers on or off
- Provide junction destination control

7.12.5.2 Field Indications

The CTC control console must provide visual indication of field conditions to the LRT Controller including the following states:

- CTC control status for a Signaling territory
- Automatic/Manual mode status for a Signaling territory
- Signal request
- Signal time locking
- Route Locking
- Signal aspects
- Signal Blocking
- Switch positioning
- Switch trailed
- Switch Locking
- Switch blocking
- Occupancy state for each track circuit or ACB section
- Track section blocking
- Station turnback mode
- Crossing activation
- Crossing gate down
- Knife switch position
- Crossing preemption

7.12.5.3 Alarms

Alarms are subdivided into categories by priority and urgency. Alarm categories define what level of audible and visual indications are presented in the LRT OCC.

Alarms that are reported by the system are:

- Red Signal overruns
- Signal light out conditions
- Switch machine failed/trailed
- Track circuit fault
- Crossing short warning
- Crossing gate fault
- Crossing traffic signal controller health
- Crossing excess operation
- Loss of power to a field location
- Low battery conditions at a field location
- Ground fault on Vital operating bank
- Door opened at field location
- Loss of VLC link
- CTC requests to the field that were not executed by a VLC
- Unexpected changes of a Train control system device state
- CTC system hardware or software errors
- Detection of an LRT Controller's attempt to log off before releasing control of the territory

7.12.6 Train Tracking

Train tracking functionality is included in the CTC system to permit identification and tracking of Trains including unscheduled Trains, test LRV, training LRV, work Trains and maintenance equipment.

The Train tracking function includes the following features:

- Assigns, verifies, and modifies Train ID (6-digit alphanumeric characters)
- Continually monitors the location and Train ID of all Trains and maintains correlation of each track occupancy with the proper Train ID and schedule
- Reports Train locations and Train IDs to the other CTC functions
- Predicts the Train location to support the announcement of an imminent Train arrival at a Station
- Displays the location of all Trains, including Train IDs, on control consoles and the status board
- Updates the tracking database as new data is received
- Provides the LRT Controller the capability to correct problems in the locations and identities of Trains including assigning a Train ID, changing a Train ID, moving a Train ID from one occupancy to another, deleting a Train ID, swapping Train IDs, and entering and changing Train consists
- Provides a convenient initialization procedure to allow the Controller to establish the Train ID of all Trains when the CTC system is initialized

7.12.7 Display Conventions

Refer to the ARINC AIM–Systems Manual for details on how various system elements are displayed on the CTC system control board.

7.12.8 Event Playback

The CTC system has event logging capability allowing full playback functionality of prior events.

7.13 INTERSECTIONS: AT-GRADE CROSSINGS

At all locations where LRT tracks cross Streets At-Grade, appropriate steps must be taken to preclude a collision between the Train and active mode or vehicular traffic does not occur. The measures as described below must be incorporated into the design and as per the Transport Canada Guidelines. There are four levels of control available for At-Grade crossings in the LRT System.

7.13.1 Methods of Control

7.13.1.1 Determining the Method of Control for LRT Intersections

The type of control for intersections where Trains cross Streets must be determined by the physical factors and geography of the crossing such as:

- Sight lines for the public
- Sight lines for the TO
- Local conditions such as land use and high pedestrian volumes

See Chapter 1, General for more information about acceptable types of intersection control based on operational and corridor constraints.

7.13.1.2 Types of Control

Passive Control

Passive control consists of static signage that provides information to the public on the possible presence of a Train. As provided in Chapter 1, General, this method of control is not permitted on the LRT System, although static signage is used to supplement the active controls described below.

Traffic Signals

Vehicle and/or pedestrian traffic signals may be used to control the intersection of Trains with pedestrians, cyclists, or motor vehicles. To achieve acceptable LRT System operation, the Design should provide Signal priority to Trains wherever practicable.

The level of warning, situational awareness, and system integrity provided by traffic signal control is not considered acceptable for Trains operating at greater than 30 km/h.

Railway Crossing Warning Devices: Flashing Lights, Bells, and Gates

Typical active railway crossing warning devices consisting of flashing lights and bells may be used to provide warning at crossings. Crossing warning devices on the LRT System are typically equipped with gates due to two-track operations. Automatic LRT preemption of traffic signals must be used near to signalized intersections.

Grade Separated Crossings

Where the LRT ROW is vertically separated from the adjacent Streets no Signal interface is required.

7.13.2 Mandatory Requirements

7.13.2.1 Shared Railway Corridors

At-Grade crossings on shared freight railway corridors are controlled by the railway and are under the regulatory jurisdiction of Transport Canada. Crossing design within these corridors must be coordinated with the railway and regulatory standards for At-Grade crossings may also apply to LRT Design.

7.13.2.2 LRT Exclusive At-Grade Crossings

For LRT At-Grade crossings not associated with freight railway corridors, Federal and Provincial governance has no jurisdiction over the crossing Design. However, Design of crossing warning systems must consider the intent of the regulations.

7.13.2.3 Second Train Warning System

Where gate arms are not provided as part of a crossing warning system, a warning system must be employed to provide audible and/or visual cues of a second Train approaching as the first Train has completed its crossing.

7.13.2.4 Crossing Sight Line and Safety Assessment

An assessment of sight lines for both the TO and crossing pedestrians, cyclists, and motor vehicles must be undertaken by the Designer according to industry and jurisdictional standards. The calculations and any resulting report must be provided in the Systems Assurance process.

7.13.3 At-Grade Crossing Warning System Design

7.13.3.1 Railway Crossing Warning Devices with Gates

This type of system operates with full LRT priority and traffic signal pre-emption. Trains are not restricted or slowed to accommodate At-Grade crossing signal conflicts. To promote the unrestricted crossing of the Street, crossing gates must be used and must be in a fully horizontal position, as described below, before the Train enters the crossing.

7.13.3.2 Design Criteria

Transport Canada regulations have no jurisdiction for LRT tracks crossing Streets, however, it is the Operator's practice to adhere to the Transport Canada Grade Crossing Standards (TCGCS) [64].

7.13.3.3 Activation of Crossing Warning System

All At-Grade Crossing Warning Systems (GCWS) must be activated by Vital Train detection in advance of the crossing. The approach lengths must provide minimum warning time in both directions on all tracks. Timers or magnetic wheel detectors may be used in conjunction with track circuits if track circuits alone fail to meet the operating requirements.

7.13.3.4 Extended Approach Concept

The Design should not have gate arms clear after the passage of one Train only to immediately descended again due to the approach of another Train. Once gates have started clearing a minimum of 10 s must be allowed before gate operation is activated again. This allows time for a minimum green interval to run and traffic to clear the intersection. To prevent delaying Trains to meet this requirement, an extended approach circuit must be used to ensure the gates remain down if another Train calls them down within 10 s.

7.13.3.5 Control Design Criteria

At-Grade crossing Signal control systems must be based on AREMA design principles.

GCWS must provide a minimum of 20 s warning time prior to the arrival of a Train at the nearest edge of the crossing. The required time must be increased based on the geometry of the crossing in accordance with TCGCS.

All GCWS must be activated by Vital Train detection and allow adequate warning time for Trains approaching from both directions and routing on all tracks. A combination of Vital Train detection and timers must be employed if detection resolution alone fails to meet the operating requirements.

7.13.3.6 Call-On Signals

A two aspect (yellow and green) Call-on Signal must be provided at the Wayside to inform the TO that the GCWS has been activated as requested. The Call-on Signal must be located at a distance from the crossing that is greater than the worst-case braking distance for a Train traveling at posted speed. A trip stop magnet associated with the Call-on Signal must initiate Train braking if the Train has failed to stop for a yellow Signal.

7.13.3.7 Traffic Pre-emption near At-Grade Crossings

At-grade crossings located near signalized intersections must provide an interface to the traffic signal control system. This interface must:

- Allow motor vehicle traffic queued on the Trackway to clear before the arrival of a Train
- Restrict traffic movement toward the crossing when a Train is approaching

The interface should also provide optional traffic cycle information to the Signal System to allow coordination of Train and Street traffic movements though the intersection.

The Designer should refer to TCGCS as a guideline to determine if preemption time is required. The Owner will review and approve traffic signal controller requirements including advance preemption time.

7.13.3.8 Stopping Distance – At-Grade Crossing

Refer to the latest version of the High Floor LRT Signals Engineering Manual.

7.13.3.9 Knife Switches

Knife switches are used as a manual method of control for crossing warning systems on the Capital and Metro Lines. Each crossing is equipped with one knife switch for each track; each knife switch controlling operation of the crossing(s) relative to the track it is associated with. Knife switches are rated to be used in Class I AREMA Vital circuits. The knife switch has three effective positions:

- Downward vertical position making electrical connection to the AUTO input circuit
- Middle position making no electrical connections
- Upward vertical position making electrical connection to the BYPASS input circuit

Knife switch status is passed to the governing Train control system.

The two input states are defined as:

- AUTO (Low = NOT AUTO, High = AUTO)
- BYPASS (Low = NOT BYPASSED, High = BYPASSED)

Where a crossing warning system provides warning for Trains operating on the track governed by a knife switch, the following table defines the behaviour of the crossing for that track:

Table 7.7.9 Knife Switch States and Corresponding Crossing Behaviour

AUTO	BYPASS	Crossing State for Associated Track	Crossing Behaviour Associated with this Knife-Switch
LOW	LOW	MANUAL	Crossing must be activated indefinitely
LOW	HIGH	BYPASS	Crossing must be unresponsive to approaching Trains on this track, acting as though no Trains are approaching on the track
HIGH	LOW	AUTO	Crossing must activate normally with Trains operating on this track
HIGH	HIGH	INVALID	Crossing must be activated indefinitely

7.13.4 Crossing Warning Equipment Requirements

7.13.4.1 Bungalow/Cabinet Requirements

All bungalows or cabinets housing crossing warning equipment must be insulated and provide heating and ventilation to maintain an environment capable of meeting the specifications of all the equipment housed in the bungalow or cabinet.

7.13.4.2 Connections to Crossing Signals

All connections between bungalows or cabinets and crossing Signals must be run through Reinforced Thermosetting Resin Conduit (RTRC) with a minimum diameter of 50 mm.

7.13.4.3 Power and Batteries

All electric and electronic components of the crossing warning system must be powered directly from a DC operating bank. The operating bank must consist of an Alternating Current (AC) rectifier/charger and a back-up battery bank in accordance with the AREMA C&S Manual of recommended practices. Refer to AREMA Section 9: Power Supply for this information.

The AC charging rectifier must be rated at sufficient amperage to continuously operate the activated crossing warning system without relying on battery bank reserves.

The battery bank must be of Nickel-Cadmium design intended for railway Signaling applications, rated to operate all crossing warning equipment under normal operating conditions for a period of 8 hours in the event of AC power loss. A minimum rating of 250 Amp-Hours must be specified.

Each Vital operating bank must be isolated from ground and all other power sources.

Each bungalow or cabinet must include a power off alarm indication to the LRT OCC.

7.13.4.4 Pedestrian/Cyclist At-Grade Crossings

Call-on Signals are not required at pedestrian/cyclist crossings with GCWS but Crossing Warning Indicators (CWI) must be provided to inform the TO that the crossing warning system has been activated. A CWI is a white dwarf Signal mounted to the outside of the track that flashes when the crossing warning system has been activated. Once the crossing gates are confirmed down the CWI will be steadily lit.

Pedestrian/cyclist At-Grade crossings with GCWS must include crossing Signals with red flashing lights, railway crossing signs, bells, emergency exit swing gates, and crossing gate arms.

Refer to Chapter 17, Streets for more information.

7.13.4.5 Clearances

The location of all At-Grade crossing warning equipment must comply with the dynamic clearance requirements provided in Chapter 3, Clearances and Right-of-Way.

7.13.5 Crossing Approaches

7.13.5.1 Definition

The Train detection section(s) in advance of an At-Grade Crossing must extend a sufficient distance to allow adequate operating time of a GCWS. Occupancy of a crossing approach will initiate activation of the GCWS.

7.13.5.2 Calculation of Approach Circuit Distance for Crossing Warning Systems

Refer to the latest version of the High Floor LRT Signals Engineering Manual for calculation methodology and examples.

7.13.5.3 Timers for Approach Circuits

When the desired crossing approach length does not closely align with practical Train detection section boundaries, Vital timers may be incorporated to delay occupancy of the approach after an occupancy segment is occupied. Timers may also be employed at Stations where occupancy of the Station detection section will occur sooner than the desired activation time of a GCWS.

7.13.6 Interactions with Signal System

7.13.6.1 Block Signal System Influence on Intersections

If a Train does not have Movement Authority to cross an intersection, the crossing warning system must not activate or send a preemption request to the traffic signal controller.

7.13.6.2 Crossing Warning System Influence on Block Signal System

Block Signals must use GCWS status as part of Signal clearing checks. The following conditions may keep a Signal from becoming permissive:

- Crossing warning system not activated or gates not horizontal, in accordance with site specific requirements
- Preemption time not yet expired
- Crossing warning system just deactivated and a minimum 10 s delay not complete
- Hold in Station functionality is employed, and the traffic signal controller is holding the Train

7.14 INTERSECTIONS: TRAFFIC SIGNAL INTERFACE

7.14.1 Pre-Emption

7.14.1.1 Links to the Traffic Control System

The Signal System sends Vital status information to the traffic signal control system to enable coordination of traffic signals with the LRT crossing warning system. Timing requirements are determined by the Owner.

Traffic signal status is provided by the traffic signal controller to the Signal System, which must provide an alarm when the traffic system is deemed unhealthy as well as displaying modified Signal aspects to alert the TO of potential conflicting states at an intersection.

7.14.1.2 Circuit Requirements

Closed-loop Vital line circuits must be provided to the traffic signal controller cabinet. Traffic signal controllers are not designed to AREMA Vital standards. As such, failure modes exist outside of the standard line circuit design and check-back circuits must be used to provide positive feedback from the traffic signal controller when a line circuit changes state. The check-back circuit to the Signal System must be of the opposite state to the line circuit sent to the traffic signal controller.

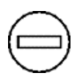
7.14.2 Traffic Signal Priority

Where crossing warning systems are not necessary, traffic signal controllers alone control Train movements at intersections. Trains must expect the traffic signal controller to show a restrictive movement indication at any time.

7.14.2.1 Transit Signal Aspects & Indications

The following traffic signal aspects must be applied for Trains where traffic signal control is used.

Table 7.10 Transit Signal Aspects and Indications

Vertical White Bar		White vertical bar indicates movement through the intersection is permitted.
Flashing Vertical White Bar	 Flashing	Flashing white vertical bar indicates that a Train should not enter the intersection, and if already occupying the intersection the Train should clear the intersection.
Horizontal White Bar		White horizontal bar indicates movement through the intersection is prohibited.

7.14.2.2 Levels of Priority

Full Priority

In full priority operation, the Signal System will inform the traffic signal controller that a Train is approaching the intersection. The traffic signal controller will provide a permissive aspect to the Train prior to entering the intersection. However, if the Train does not arrive at the intersection within an allotted time, the traffic signal controller may be programmed to truncate the permissive phase for the Train.

Partial Priority

In partial priority operation, the Signal System will also inform the traffic signal controller that a Train is approaching the intersection. The traffic signal controller may be programmed to modify the traffic signal phases to minimize the delay to the Train, however the Train may be required to stop at the intersection until the conflicting traffic phases have completed and the Train movement through the intersection is permitted.

7.14.2.3 Interactions with the Fixed Block Signal System

The traffic signal controller must accept operation of Trains in both directions on both tracks including turnback operations. If a Train does not have Signal authority, the traffic signal controller must not be informed of an approaching Train until the Train gains authority to pass through the intersection.

7.15 HARDWARE: GENERAL

Equipment not previously used on the LRT System that is proposed for use must have a proven performance record with major North American and/or European public transportation agencies that operate heavy rail or LRT Systems.

For detailed signal hardware requirements, refer to the latest LRT High Floor Signals Engineering Manual.

Due to weather conditions in Edmonton, all new outdoor Wayside equipment must be rated for temperatures that meet or surpass the summer and winter conditions as provided in Chapter 1, General.

In addition, all outdoor equipment must:

- be sufficiently reliable to meet the overall operational targets of the project
- be weather and water resistant as per AREMA C&S Manual of Recommended Practices

The Design should minimize the number of different equipment suppliers to:

- reduce or eliminate interfacing requirements
- minimize the amount of additional staff training
- maintain consistency in operational functionality
- consolidate spares inventory and control

7.15.1 Approved Products

A list of pre-approved products for use on the LRT System will be provided by the Operator.

7.15.2 Electromagnetic Compatibility

Any interfacing equipment or systems, including track circuits where applicable, must be electromagnetically compatible with the worst-case conducted and inductive emissions from LRVs the TPS, and the OCS, as well as from radio systems.

Any equipment for interface purposes should conform to IEEE STD 1100-1999 [65], and emissions of Signal equipment must conform with EN50121-4:2006 [66].

7.16 HARDWARE: SIGNAL ROOMS

The Signal control system must be a Vital solid-state controller installed in a SER controlling the Wayside Signal equipment for a specific territory. It must be integrated with the CTC system to form an integrated Signal System compatible with the existing LRT System.

7.16.1 Climate Control

Refer to Chapter 12, Mechanical, for typical environmental design requirements for Signal rooms. All equipment installed in a SER must be capable of operating over a temperature range of 0° C to 35° C. When battery venting, safe air exchange or any other environmental conditions are required, coordination with the mechanical Designer is required.

7.16.2 Computers

A computerized LCP for on-site access to the Signal territory VLC system must be provided. The computer must be connected to the Signal network to allow VLC troubleshooting, configuration, and log retrieval.

7.16.3 Power Systems

The Design must include an adequate electrical power supply as provided in Chapter 11, Electrical.

Computer and other solid-state equipment must be provided with surge protection and UPS power to manage momentary power surges and losses.

All power circuits up to low voltage transformers or power supplies are governed by the Canadian Electrical Code (CEC). Vital energy banks must be governed by the AREMA Communications and Signals Manual Section 11: Circuit Protection [67] .

7.16.3.1 Power Back-up Systems

All Signal control equipment must be provided with a UPS for a minimum of eight hours of continuous operation unless an automatic backup generator system is provided, in which case a minimum of two hours of stand-by power is acceptable.

7.16.3.2 Ground Isolation

Grounding and bonding systems must meet AREMA Communications and Signals Manual Section 11: Circuit Protection [67].

Ground fault detectors must monitor all ungrounded Vital power systems.

7.16.3.3 Surge Protection

Proper use and interconnection of Surge Suppression Devices (SSD) must be provided for all power and control circuits entering and exiting a SER or bungalow.

7.16.3.4 Alarms

Power related alarms must be provided via CTC and LCP for the following conditions:

- low battery voltage for each operating battery bank
- ground fault for each isolated operating bank
- power off

7.16.3.5 Generator Plug

All Signal Rooms must have a generator plug where power can be provided.

7.16.4 Signal Room Equipment

All Wayside Signal equipment must be controlled by a stand-alone VLC located in the SER or Wayside Signal bungalow. One or more VLCs in the SER must control the Wayside Signals equipment within its territory independently.

Where Vital software must be employed, the overall system must be designed on the check-redundancy principles defined in Section 7.5.4.2. Systems must be proven to be independently safe from external influences such as Electromagnetic Interference (EMI), interfaced systems or sub-systems, and human operation from either the LCP or CTC.

7.17 HARDWARE: BUNGALOWS, JUNCTION BOXES AND CASES

All bungalows, junction boxes and cases must be corrosion and weather-proof. Bungalows and enclosures must be insulated and be equipped with Heating Ventilation Air Conditioning (HVAC)systems capable of venting battery gas at a safe air exchange rate. Refer to Section 11: Circuit Protection in AREMA [67] for details on the environmental limits of equipment.

All bungalows, junction boxes, and cases must be sealed to prevent access by insects and rodents.

All bungalows, junction boxes and cases for the Wayside Signal equipment must be clear of the Design Vehicle Dynamic Envelope (DVDE) as provided in Chapter 3, Clearances and Right-of-Way.

7.17.1 Equipment Requirements

7.17.1.1 Power Requirements

Bungalows are typically designed and manufactured for use with single phase 120/240 VAC power feeds. A typical breaker panel is rated at 100 Amperes. ROW electrical power must be provided as provided in Chapter 11, Electrical.

All bungalows, junction boxes, and cases must have a generator plug where power can be provided.

7.17.2 Wayside Equipment

The Signal Wayside system must be designed to minimize the number of Wayside boxes distributed across the LRT System to optimize maintenance and troubleshooting activities.

Signal cables terminating at a termination panel for Wayside field equipment connection must have the termination panel above grade within a weather-proof enclosure.

7.17.2.1 Location of Wayside Equipment

All Wayside equipment must be clear of the DVDE. For detailed information on Train clearances refer to Chapter 3, Clearances and Right-of-Way and the figures contained therein.

7.18 OTHER: SYSTEM INTERFACES

The Signal System must be designed to properly interface with other major LRT System elements as follows.

7.18.1 Drainage

All devices that are located below grade or in proximity to the ground must be designed to provide adequate drainage to prevent the accumulation of water, snow, and ice.

7.18.2 Switch Blower Interface to Replace BMS

Control and status indication of Cold Air Blowers (CAB) at switches are to be included as part of the Signal infrastructure. The interface to each CAB may be Non-Vital. Provisions must be made to allow for the LRT OCC to turn on blowers and to provide an indication that blowers are operating.

7.18.3 Traction Power Substation Return

The Signal Design must recognize that negative TP is connected to rails via the centre tap of an impedance bond.

7.18.4 Traffic Signals

Whenever a Street crossing is required, the Signal System must be properly coordinated with the traffic signal controller at these locations as it impacts:

- Approach time
- Extended approach time
- Crossing warning Signal layout design

The Signal System must be compatible with the traffic signal controller to optimize intersection capacity, and Train operation.

The Capital Line and Metro Line use an advanced interface to the traffic signal control system that provides full priority to Train movements, as well as a targeted preemption function that optimizes pedestrian, cyclist, and motor vehicle movements through the Transportation Corridor.

Trains must preempt traffic signals on approach to an At-Grade crossing with consideration of two data points from the traffic signal controller included in the Vital circuitry of the Signal System that allow a Train to be held in a Station to wait for an optimal point in the traffic signal cycle prior to being released. The data points are as follows.

Traffic OK – True if all components of the traffic signal controller are operating correctly. If this point is not true, all data received from the traffic signal controller will be ignored by the Signal System.

Hold In Station – True if the traffic signal controller requires the Train to wait in the Station for an optimal point in the traffic cycle prior to being released.

7.19 OTHER: TESTING AND COMMISSIONING

All testing and commissioning must be carried out as provided in Chapter 1, General.

CHAPTER 8

Communications

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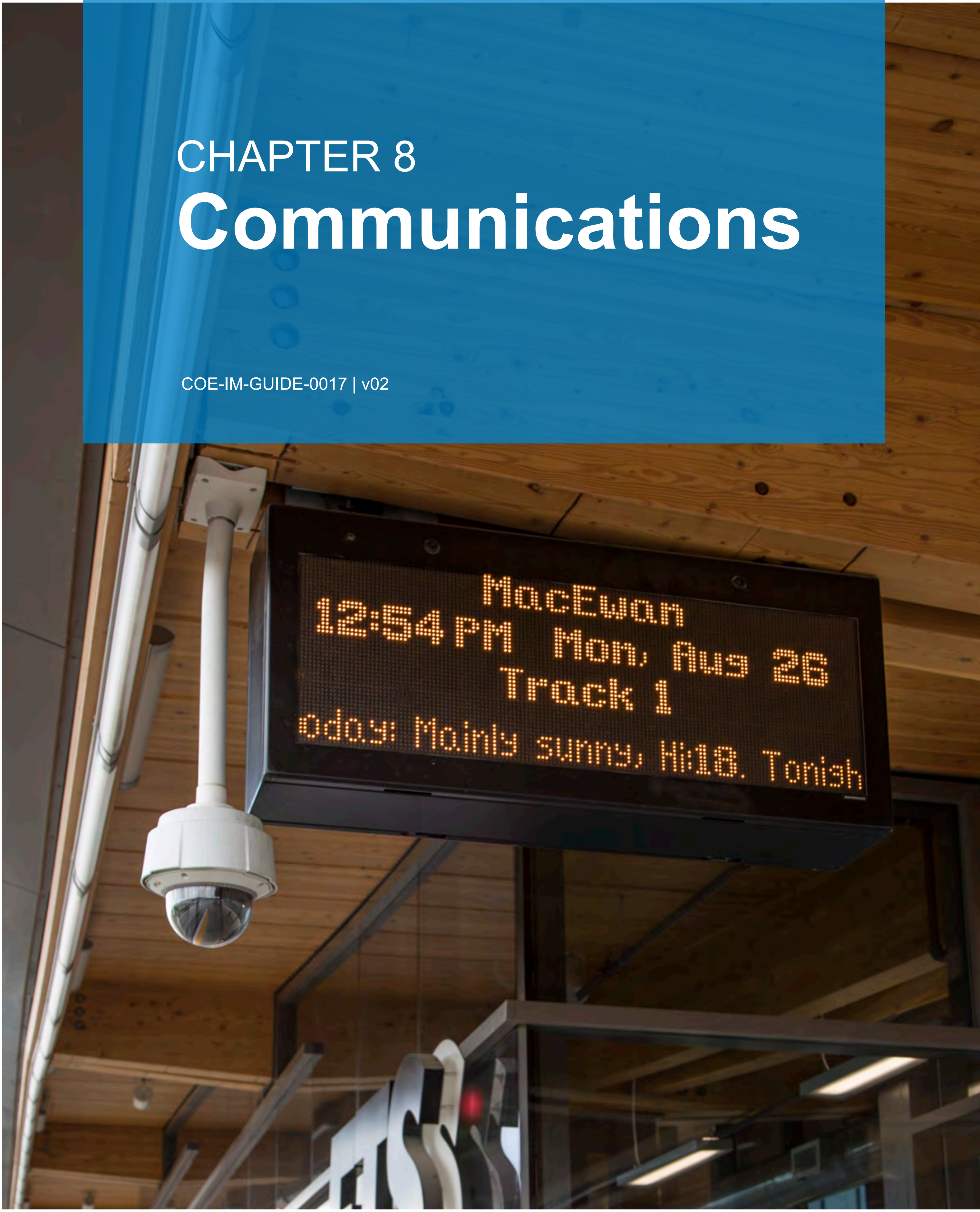

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INTENT OF USE

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See complete Intent of Use Statement following the cover page.

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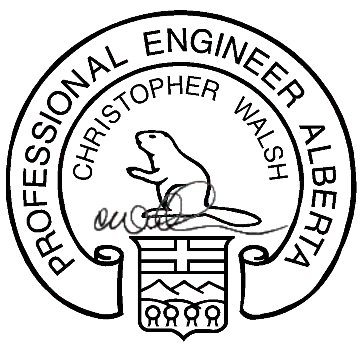

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The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

8 COMMUNICATIONS

8.1 INTRODUCTION

This chapter presents guidelines and design criteria for the design of Communications subsystem including cabling, network interfaces to common equipment and services, subsystems and interfaces for LRT stations and platforms, and related facilities for Edmonton’s High-Floor LRT System.

8.1.1 Common Infrastructure Environment (CIE)

The Operator provides a Common Infrastructure Environment (CIE) that supports core services for the communications network, server computers, and centralized storage, which include the following core platforms:

Network: Multi-Protocol Label Switching (MPLS) services architecture that meets the network requirements of subsystems such as Signaling and Train Control, real-time Supervisory Control and Data Acquisition (SCADA), Closed Circuit Television (CCTV), PA/VMS - audio-visual passenger information, Phones, Fare Collection, Intrusion Detection and Card Access Control, WiFi, Distributed Antenna System, network management, and network security. The Network platform is the backbone for the entire Operator communications system and is centrally configured, monitored, and controlled by the Operator.

Compute: Virtual machines or bare metal servers that provide hosting to any application that needs compute servers, with provision for full failover and disaster recovery. The compute platform is centrally configured, monitored, and controlled by the Operator,

Storage: Storage Area Network (SAN) that provides capabilities such as boot from SAN, storage to run hosted applications, and archival storage for backup of all data. The Storage platform is centrally configured, monitored, and controlled by the Operator.

All servers and devices are hardened to ensure the strictest levels of security and best practices for each subsystem connected to the Common Infrastructure Environment (CIE).

The network uses several methods for identity management including Windows Active Directory, Red Hat iDM, Lightweight Directory Access Protocol (LDAP) for end devices central authentication, LDAP with two-factor authentication, Remote Authentication Dial-In User Service (RADIUS), and RADIUS with two-factor authentication.

All DNS, DHCP, security and IP address management functions are controlled by centralized infrastructure maintained by the Operator.

These core platforms and the services that they provide provide 99.999% availability (five minutes downtime in one year) on a 24/7 basis. They can be fully maintained without suspending any service.

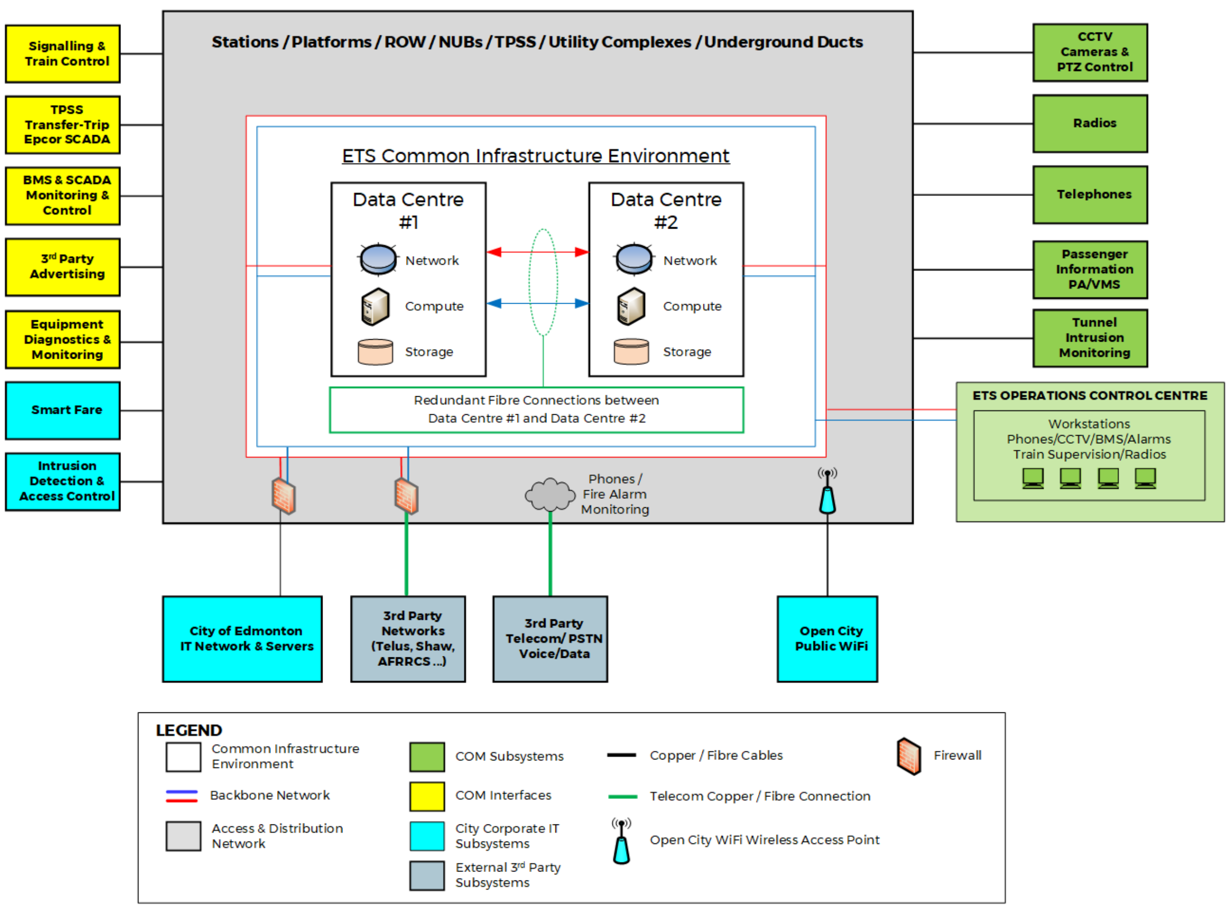
Designers of communications subsystems must incorporate these core services into their design and deployment. Applications must be hosted on the Operator provided network, compute, and storage platforms. Designers and suppliers must work closely with the Engineer, who will coordinate their requirements with the Operator.

8.1.2 Communications Systems Conceptual Overview

Chapter 1 A conceptual overview of the major subsystems and interfaces to the CIE are shown in Figure 8.1. It is a concept model intended to provide an overview of the CIE architecture for discussion purposes only; it is not intended to be a detailed set of drawings showing the physical and logical configuration of the CIE or the endpoint services and devices. The communications system includes the following subsystems:

- Operator's Common Infrastructure Environment
- CCTV Cameras and Pan/Tilt/Zoom Control
- Radios - AFRRCS
- Telephones
- Passenger Information – PAVMS
- Tunnel Intrusion Monitoring
- Signalling & Train Control interface
- BMS monitoring and control interface
- Traction Power – Transfer-Trip and EPCOR SCADA network interfaces
- 3rd Party Advertising and Telecom interfaces
- Owner IT Network interfaces for Fares and Access Control

Figure 8.1 Communications Systems Conceptual Overview



8.1.3 Urban-Style LRT

The Designer must be familiar with the LRT System and the various Station types that exist in the current system. As new Stations are built or existing Stations renovated, Designs must demonstrate the Owner's desire for an Urban-Style LRT, meaning that Stations will likely not have dedicated communications equipment rooms or supporting infrastructure such as network switches, amplifiers or equipment that has been typically housed in a Station equipment room on the existing LRT System.

Designs must use standardized and proven components currentlyin use by the Operator, as much as reasonably practicable, to enhance quality, availability, and maintainability of facilities and communications subsystems.

8.1.4 Identification and Naming Conventions

Designs must follow the current identification and naming conventions used by the Operator, including the following:

- Cable Labeling and Identification
- Cable Jacket and Wiring Color Codes
- Naming conventions for the various systems and system components

8.1.5 System Integration

All Design disciplines must coordinate their design activities with each other. System Integration engineering must be used to properly interface the many different Station and Right-of-Way (ROW) elements. Refer to Chapter 1, General.

8.2 CERTIFICATIONS

8.2.1 Railway Certifications

- EN 50121-4 [66]
- IEC 62236-4 [68]

8.2.2 Regulatory Compliance

- European Telecommunications Standards Institute (ETSI) Standards
- American National Standards Institute (ANSI) Standards

8.2.3 Electrical Safety Compliance

- UL 60950-1 [69]

8.2.4 Electromagnetic Compatibility

- CE Mark
- EN
- ETS
- FCC
- VCCI Class A

8.2.5 Electromagnetic Compatibility Compliance

- FCC
- AS/NZS CISPR

- CISPR
- ICES

8.2.6 Electromagnetic Compatibility Immunity

- EN 300 386 [70]
- IEC/EN 61000-4-3 Radiated Immunity [71]

8.2.7 Safety Standards Compliance

- FDA CDRH 21-CFR
- UL/CSA 60950-22 [72]
- CSA-C22.2 No.94.1 [73], CSA-C22.2 No.94.2 [74]
- CAN/CSA-B72-M87 [75]
- UL50 [76]
- IEC/EN 60950-22 [77]
- IEC 60529 [78]
- cTUVus, CB

8.2.8 Other Certifications

- MEF CE 2.0
- NEBS Level

8.3 APPLICABLE CODES, STANDARDS, AND REGULATIONS

In the case of a conflict between standards or regulations the more restrictive requirement will apply.

8.3.1 Codes and Standards

All design work, equipment and material selection must conform to or exceed the latest editions of the codes and standards issued by:

- City of Edmonton Community Standards Bylaw 14600 (Noise Provisions) [79]
- City of Edmonton Facility Design & Construction Consultant Manual, Volume 1, Design Process and Guidelines v4.0 [80]
- City of Edmonton Facility Design & Construction Consultant Manual, Volume 2, Technical Guidelines v4.0 [81]
- Alberta Occupational Health and Safety (OH&S) Act [82]
- Alberta Chemical Hazards Regulations
- Alberta General Safety Regulations
- Canadian Electrical Code C22.1-18 [42]
- American Public Transportation Association (APTA) Standards
- Electrical Equipment Manufacturers Association of Canada (EEMAC) Standards
- European Committee for Electrotechnical Standardization (CENELEC)
- International Organization for Standardization (ISO)
- Guidelines for Non-Ionizing Radiation IRPA/INIRC
- ASHRAE 55-2017 – Thermal Environmental Conditions for Human Occupancy [83]
- ASHRAE 62.1 [84] and ASHRAE 62.2 [85]
- ANSI/IES-RP-7-17 – Recommended Practice for Lighting Industrial Facilities [86]
- CSA-Z412 – Guidelines on Office Ergonomics [87]

- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Underwriters Laboratories (ULC) Inc. Standards
- Boeing Specification Support Standard BSS 7239 Test Method for Toxic Gas Generation
- ASTM E162 Flammability Test
- ASTM E662 Smoke Density Test
- NFPA 262, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces
- UL 723 (ASTM E84) Test for Surface Burning Characteristics of Building Materials,
- ULC S102.2 Surface Burning Characteristics of Flooring, Floor Covering, and Miscellaneous Materials.
- Insulated Cable Engineers Association (ICEA) (latest edition)
- ICEA S-87-640 - Optical Fiber Outside Plant Communications Cable [88]
- Telecommunications Industries Associations (ANSI/TIA) (latest editions)
    - ANSI/TIA-568-D [89]
    - ANSI/TIA-568.2-D: Balanced Twisted-Pair Telecommunications Cabling and Components [90]
    - ANSI/TIA-942-B [91]
    - ANSI/TIA-606-C [92]
    - ANSI/TIA-607-D [93]
    - TIA-102.x Series: Telecommunications, Land Mobile Communications (APCO/Project 25) [94]
- Building Industry Consulting Service International (BICSI) (latest editions)
    - ANSI/BICSI 007: Practices for Intelligent Buildings and Premises [95]
    - ANSI/BICSI 002: Data Center Design [96]
    - ANSI/BICSI 005: Electronic Safety and Security (ESS) [97]
    - ANSI/BICSI 006: Distributed Antenna Systems (DAS) [98]
    - ANSI/BICSI 008: Wireless Local Area Network (WLAN) [99]
    - ANSI/BICSI N2-17: PoE Installation [100]
    - BICSI G1-17: Outside Plant (OSP) - General [101]
    - ANSI/NECA/BICSI 607: Bonding and Grounding [102]
- Institute of Electrical and Electronics Engineers (IEEE) (latest editions)
    - IEEE 802.1 series [103]
    - IEEE 802.3 series [104]
    - IEEE 802.11a/b/g/n [105]
    - IEEE 802.16d WiMAX [106]
    - IEEE - C62.41.1 [107]
- International Telecommunication Union (ITU) (latest editions)
    - ITU-T G.652: Characteristics of a single-mode optical fibre and cable [108]
    - ITU-T G.984: GPON Gigabit-capable Passive Optical Networks [109]
    - ITU-T G.988: ONU management and control interface (OMCI) [110]
- Telecordia (latest editions)
    - Telecordia GR-1089-CORE [111]

- Telecordia GR-63-CORE [112]

- Internet Engineering Task Force (IETF) (latest editions)
  - RFC 791 - IPv4 [113]
  - RFC 2460 - IPv6 [114]
  - RFC 2475 - QoS/DiffServ [115]

- Association of Professional Engineers and Geoscientists of Alberta (APEGA) standards

8.3.2 Current Products and Approved Products List

All communications equipment and infrastructure must be current technology at time of design and construction. Specifying and/or installing equipment that is end of support, end of sale, or end of life is not acceptable. Designers must refer to the Operator’s Approved Products List provided by the Engineer.

8.4 GENERAL DESIGN REQUIREMENTS

8.4.1 Design Goals and Objectives

Designs must minimize the number of components used in communication systems and all systems must be designed with a focus on integration. Physical segregation of common system equipment in communication rooms must be avoided. All operator functions must be capable of being installed and used on shared operator workstations in the OCC. The user interface/Human Machine Interface (HMI) for an application will not require dedicated individual workstations. A critical component of any communications system is the ability to centrally monitor and assure that the system is operating as designed. Any solution installed in the Operator’s environment must have a monitoring and assurance solution incorporated as part of the main system design, capable of being integrated with the existing Operator’s automated maintenance management system.

Designers must prepare a Design Basis Memorandum (DBM) outlining the Owner’s requirements and describing how the system design functions within the Operator’s infrastructure. Consistency from one site to another must be applied. The organization and layout of most types of communications facilities must be followed in deployment of new sites.

The Total Cost of Ownership (TCO) must be considered for a communications system solution. Various factors should be considered including capital costs, maintenance costs, costs of additions, changes, and deletions, resources needed to operate and maintain, integration with existing or future applications or subsystems, longevity, and evidence of field proven operation of the solution in comparable circumstances that meet all requirements. Any interconnections and dependencies between systems such as timing, functionality, hardware, wiring, network interfaces, or software interfacesmust be clearly documented in the design, including analysis to show how the links between subsystems affect each for upgrades and/or cutover to existing infrastructure. Redundancy must be considered for every point in the system and must reflect end-user service demand and availability, power, cooling, weather, network connections, and local hardware.

8.4.2 Design Documentation

The Design must incorporate detailed product and point-to-point wiring diagrams to the extent known during design. For example, if specific communications devices are sole-sourced based on system standardization, then the design submissions must include product information and full point-to-point wiring diagrams. For products that will be procured during the project, which includes any device whose specifications can be met by a variety of suppliers, the Design must provide typical device information and wiring diagrams to communicate the Design intent without full detailed vendor information and point-to-point wiring diagrams.

Where practicable the IFC drawings should incorporate all vendor information and point-to-point wiring diagrams. For products that are procured during the project, this approach requires shop drawing submissions, reviews, and acceptance between the IFT and IFC design submissions. If there is insufficient time to complete the shop drawing process between the IFT and the IFC then the Designer must include all shop drawings and point-to-point wiring diagrams with the record drawing submission.
Where precise details of cable and conduit runs to end devices are needed, the drawings and specifications must include notes to indicate that this information will be provided by the trade contractor in their shop drawing submittals.

The Operator uses various software for documenting cable connections and rack layouts. All design and as-built documentation must be added to these documentation systems as part of any project that requires changes to the cabling system or adds new equipment in communications cabinets.

At minimum, a drawing set for communications system Designs must include the following:

- Cable and conduit schedules with field level cable and conduit labels identified and unique to the location they are installed in.
- Site plan and analysis of field of view and obstructions for camera placement and sight lines, showing all major obstructions including buildings, bridges, large signage, and trees.
- Site plan showing end device locations, cable distances for CAT6 and Powered Fibre with #12, #16 or #18 AWG conductors.
- Overall block diagrams and detailed block diagrams showing device names.
- Floor plan layouts for equipment locations and rack locations
- Equipment rack layouts and bill of materials.
- Port assignments for network switches, terminal servers, out-of-band device serial ports.
- VLAN and IP address assignments of all devices on device schedules.
- Fiber patch panel layout and labels.
- Power bar layout and power system diagrams.
- Cable schedules with cable type, cable lengths, colour code, connector type
- Equipment schedules with equipment types, models, power budget, dimensions
- Mounting details for field equipment
- End device drawings showing typical media converter installations.

Drawings that must be provided either at the shop drawing or as-built stages must include updates to the drawings listed above and the following:

- Drawings showing all devices connected to head end with details such as network switch ports, cable names, and what conduits cables go through.
- Drawings showing conduit runs and boxes, and names for all.
- Drawing showing any splice boxes, terminal block, and similar devices.
- Drawings for each of TVSS, Synergis, DC plant, OSE and field device OSE, DC distribution box, BIX, Telus Demarc, C-Cure, speaker terminal box, fire alarm auto-dialer.
- Fiber splice diagrams.
- Field cabling layouts.
- Serial cable layouts.
- BMS (or control system) card I/O loop drawings

8.4.3 Heat Rejection and Ventilation

Equipment placed within a facility must be listed in a summary table in the drawing package which identifies the heat rejected by the equipment and any potential ventilation requirements for the battery system. This information must be updated in the as-built drawings for the facility so that it can be used as a technical reference by the Owner or Operator.

8.4.4 Equipment, Devices, and Components

All equipment must be remotely manageable both in band and out of band.

All servers are currently centrally located in the two main ETS data centres. Communications designs that require servers must be based on server platforms located in these data centres as part of the CIE.

Any new devices that are not currently used by the Operator and are proposed in a Design must be reviewed by the Engineer in consultation with the Operator, and if found necessary a BCP document must be created by the Designer and submitted to the Engineer for review and approval.

All components in communications rooms must be capable of being installed in a 19 in rack mount cabinet or rack and being densely installed. Chassis-based modular units with redundant power supplies must be used.

8.4.5 Powering

8.4.5.1 Communications AC and DC Power Module (CADPM)

All communications equipment must be powered by a high availability power source, typically installed at a Utility Complex. The use case for uninterruptable power or some other mechanism to achieve this will rely on communications Designers to exercise appropriate system integration and coordination with electrical power Designers. This includes all endpoints, headend equipment and wiring closets.

Individual stand-alone power units, such as an UPS contained in a remote cabinet, are not permitted.

The CADPM must be a combination of AC and DC systems supplied by Alpha Technologies and a Battery Plant supplied by C&D Technologies Inc. Alpha Technologies must provide a shop drawing submission, to be included in the Design, showing rack layouts, number of inverters, rectifiers, and batteries with specifications of their components to the Engineer and the Designer for review and approval prior to procuring any equipment.

The purpose of the CADPM is to provide a high availability AC and DC power supply for communications systems equipment serving various Operator facilities, such as LRT Platforms, marshalling cabinets, communications rooms, and server rooms.

The major components of the Alpha Technologies UPS are the CXPS-HX/CXPS-W rectifiers, AMPS HP-2 inverters, and the XMBS 250/XMBS 100 with Auto-Sync wall-mounted external bypass switch. DC distribution for the UPS is provided by Alpha Smart E2s and eLimiter+(s), which supply -48 VDC and -57 VDC to end devices. The battery plant and cabinet are provided by C&D Technologies.

Refer to CADPM DSD.

8.4.5.2 Automatic Transfer Switch (ATS)

In Comms equipment rooms and server rooms, where a where a dual source of power has been installed, such that “A” power source fails over to “B” power source, Designs must include the option to connect any equipment having a single AC input to an Automatic Transfer Switch (ATS), so that it can be automatically transferred from the “A” to “B” power source or “B” to “A” power source.

8.4.5.3 Powered Fibre

Power and data must be carried on the same cable where practicable and allow for centralized management of an end device. End devices should be powered from a CADPM, a central DC power source located at the closest Utility Complex. A Power Over Ethernet (PoE) adapter must be used to convert centralized DC power per end device. Powered fibre solutions should be used for any device beyond a distance of 90 m from a network switch.

Powered fibre is the Operator's standard for all installations, replacing traditional copper ethernet cabling. Facility designs should incorporate Fibre Distribution Hubs (FDHs) at strategic locations throughout the facility to provide connectivity to nearby communication end devices.

For devices that cannot connect directly to a powered fibre cable, a media converter must be installed to convert the DC power and fibre connection to a copper PoE connection. These media converters should be installed as close as practicable to the end device (e.g. mounted in a pole base rather than in a marshalling cabinet on the platform).

Sufficient slack must be left in the powered fibre cable to allow the cable to be connected directly to the end device in the future by removing the media converter and connecting a new end device that accepts powered fibre natively.

8.4.6 Wireless Solutions

Wired connectivity must be provided wherever practicable. When wireless connectivity is required (e.g. a remote camera on a parking lot pole) all design details must be documented in the Design and approved by the Engineer.

8.4.7 Remote Power Control Management for PoE Devices

Designs and installations must provide the ability to remotely power cycle any PoE device such as a phone or camera. PoE powered devices, network switches, PoE injectors and PoE midspans must be manageable and able to remotely power cycle the end device.

8.4.8 Entrance Conduits and Terminal Blocks

Conduit must enter a communications room at either ceiling level or floor level, located on a single wall, and should be on the side of the room nearest to the Trackway or system-wide duct-bank. The Design must include a 20 mm fire retardant treated (FRT) plywood, painted grey and compliant with ASTM E-84/UL 723 Class A flame spread and smoke developed indices, such as U-TECK Fire Retardant Backboards for Telecom and Datacom Equipment Installations. The backboard must be a minimum of 1.2 m wide and mounted floor to ceiling. The width must allow for cables to run up to a cable tray and the backboard must also hold gas tube protector cabinets, wall mount fibre splices, and the associated cable management.

8.4.9 Low Voltage Conduits and Distribution

All communications wiring must be in a conduit or in a cable tray. Communications infrastructure such as cables or devices must not be supported by architectural suspended ceiling supports or being laid on ceiling tiles.

Wall mounted cabinets for systems such as BMS, card access control and RTU must be provided, along with a junction box for PA system speaker and microphone wiring. Low voltage conduits must also include OSE, surge arresters, and ground bus bars.

8.4.10 Surge Arrestors

All outdoor CAT6 runs must have surge arrestors installed at the base of a device to prevent surges from entering the communications room.

All outside plant copper cables must be terminated on protector blocks. Refer to Operator's Approved Products List.

All cameras installed outdoors must have CAT6 in-line surge/lightning arrestors with PoE pass-through on the data cable. This device must be installed at the base of the pole or in the junction box located nearest the camera in the case of building-mounted devices. All surge/lightning arrestors must be provided with a proper ground connection, in accordance with the manufacturer's specifications and meeting CAN/CSA-B72-M87 [75], UL-497B [116] and TIA/EIA 607 [93] grounding and surge suppression requirements.

Surge arresters must also be located on all CAT6 cables at the building cable entrance points. The grounding point at the entrance must tie into the communications room grounding system. The building entrance design must prevent any voltage potential buildup or surges from lightning along the cable length between the surge arrestor ground at the device and the building ground.

8.4.11 Grounding

Grounding design must mitigate the effects of ground loops and electromagnetic interference. The Designer must provide chassis ground and signal ground systems as follows. The chassis ground must tie into the building traditional ground system along with other systems in the building. The signal ground is referenced to the circuit devices and must be isolated from the chassis ground, since Signalling, and Traction Power Systems (TPS) can induce noise into the ground system.

Designs must prevent ground loops and must include a note on drawings and in specifications that ground loops are not permitted in cables connecting end devices. Connecting a cable shield to a grounded patch panel at the equipment room end and grounding this shield at the device end, when the end device chassis is also independently grounded is not permitted.

The Design must use oversized main ground bus bars. Resistance to ground from each ground bus bar must be 10 Ω or less for chassis ground and 5 Ω or less for signal ground. Refer to Operator's Approved Products List.

A ground wire must have its own two-hole lug connector to attach that wire to the ground bus bar to eliminate stress on the ground wire and the prevent the connection from rotating loose. Double-lug connections where multiple ground wires are attached to one lug are not permitted.

8.4.12 Equipment Racks

Equipment racks must comply with E.I.A. specifications for rack mounting ANSI/EIA standard RS-310 [117]. Designs must specify equipment racks in accordance with those currently in use by the Operator.

8.4.13 Equipment Enclosures

- All enclosures must meet the requirements of the NEMA 4 standard as a minimum. For outdoor locations, water and dust resistant gaskets and water-tight connectors for wiring must be provided and be able to withstand power washing without water ingress at any location.

Applicable standards include the following:

- IEC/EN 60529 [78]
- IP66/67 [118]

- ISO 20653 [119]
- IP6K9K [120]
- NEMA 250 Type 4X [121]
- IEC/EN 62262 IK10 [122]
- IEC 60068-2-1 [123]
- IEC 60068-2-2 [124]
- IEC 60068-2-6 [125]
- IEC 60068-2-14 [126]
- IEC 60068-2-27 [127]
- IEC 60068-2-78 [128]

Designs must consider the option for enclosures and fittings to be made from stainless steel or hot-dipped galvanized materials and this option will be subject to review by the designers, engineer, owner, and operator. Raw steel or other materials that could suffer damage from corrosion effects such as rust or galvanic corrosion will not be acceptable.

8.4.14 Out of Band Access

Out of Band (OOB) consists of out of band management serial terminal servers and a separate management network. The management network is a ring of gigabit switches and the serial servers connect to the network management ring.

All management ports of devices in a communications room connect to the management switches or the serial servers. These OOB terminal servers must meet the specifications of those currently in use by the Operator.

Designs must include a separate, redundant network that does not connect to the main network backbone that will be used for remote access to devices that support OOB access to configure and reboot equipment. Each communications room must be connected to the OOB network. Critical systems that require OOB access include the following:

- Network devices
- PoE injectors
- Telephone gateways
- Amplifiers
- PDU
- UPS
- Video encoders
- Remote PA servers

8.5 COMMUNICATION CABLING REQUIREMENTS

Cabling Design must provide consistency in Designs and installations on the communications system. Cabling design must meet commercial or industrial requirements depending on location. All cabling Designs and installations must follow communications standards listed in Section 8.2 and 8.3, including the latest BICSI and TIA standards.

All telecommunications cable must be installed in conduit, cable trays or duct banks unless there is a variance approval from the Owner.

Cabling Design must include the following:

- Wiring diagrams of cables and interconnections clearly showing each cable with ID, cable type, demarcation point, and any other significant transition points such as splices or slack coils.
- Riser diagrams for each station or facility showing both horizontal and vertical cable runs, transition points, slack coil placement, support, and demarcation points. Each diagram must clearly identify each cable, conduit, room, cabinet, and pull box.
- Cable schedules showing in detail, each cable run from termination point to conduits and pull boxes, to termination point for both wayside and station cabling.
- Conduit schedules for all communications conduit which clearly show which cables are placed in which conduit and their fill ratios and calculated pulling tensions.
- Termination schedules showing wire by wire or fibre by fibre detail of each termination, patch, cross connect and splice.

Fibre cabling design calculations must include the following:

- Span loss (total loss of span from patch panel to patch panel)
- Optical loss margin defined as the additional loss that can be added to a fibre optic
- Return loss (as measured from a matching connector)
- Splice loss
- Termination loss
- Physical distance to all fibre features correlated with actual track chainage positioning

Cabling design must meet the following minimum test performance criteria:

- CAT6 certification for network cables, plugs, jacks and cross-connects
- Fibre optics splices < 0.1 dB loss
- Fibre optics terminations < 0.25 dB loss and better than -55 dB return loss (matching)
- Fibre optics total loss < calculated span loss
- Fibre optics optical loss margin > 10 dB

The cabling requirements for stations and other facilities must meet the following minimum requirements.

- Only non-hygroscopic gel may be used in cables for water-blocking, which must meet all the requirements of current industry standards such as ICEA S-87-640, Telcordia GR-20-CORE and RUS PE-90.
- If cables are designed for wet locations, additional protection must be obtained with super absorbent water absorbing polymer tape.
- Fibre cables may use a tight-buffer configuration as well as loose tube.
- Cables installed in Stations and Ancillary Facilities that are intended for either staff or public use must comply with the toxicity requirements listed in Section 8.5.3.
- PA cables must be routed in a separate conduit system or shielded to prevent inductive coupling and the introduction of noise into the PA system.

8.5.1 Cabling and Wiring Methodologies

Cable management must be included in cable Designs for all LRT facilities. All cabling must be kept in neat bundles with Velcro wraps within cable trays, waterfalls, wireways in cabinets, and cable management bars on the rear of patch panels.

- CAT6 cable runs must be less than 90 m long and continuous from jack-to-jack
- Installing plugs on either end of a cable and plugging directly into devices is not permitted
- If a device requires CAT6 wires to be screwed down to terminals, then a CAT6 pigtail must be used (see.g. Belden C632206xxx: patch cord with one end cut off; RJ45 to blunt).

- All copper and fibre cables must be kept separate within communications cabinets and cable management raceways.
- Copper must be kept to the left side and fibre is kept to the right side in racks and cabinets.
- All power connections must be organized in the rear of the cabinet.

Maximum fill ratio of any conduit must not exceed 40%. All conduit 90° bends must have communication elbows that have a bending radius of 11x the cable diameter. Electrical 90° fittings or bends are not permitted in communications wiring. There must not be more than 180° (2x90°) of cable and conduit bends between pull boxes.

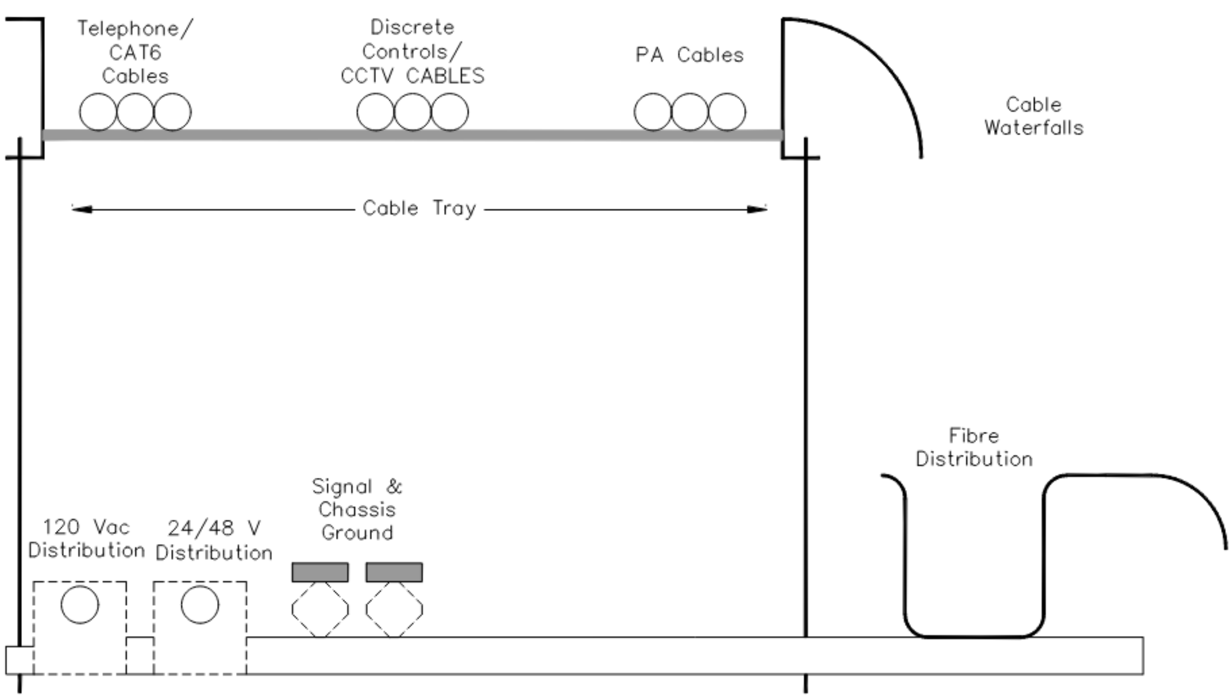
Cabling to devices at outdoor locations must include a surge suppressor at the base of the device and at the building cable entrance points, which must be connected to ground.

8.5.2 Cable Tray and Conduit - Cabling Structure

Design of cable runs within cable tray structures and conduits must minimize coupling of induced voltages and crosstalk between cables belonging to various systems. Cables and devices must not be supported by attaching them to architectural suspended ceiling supports and must not be laid on ceiling tiles.

The Design must physically separate cables to prevent cable damage and support cable management for data cables, audio cables, fibre optic cables, or heavy multipair cables. Figure 8.2 shows a typical cable layout for a cable tray. Cable ties or lacing must be used to hold cables in place.

Figure 8.2 Preferred Cable Layout in Cable Tray



The cable tray layout must have the following characteristics:

- The distance between PA system audio cables and any telephone, CAT6, or power cable must be maximized
- Fibre cables must be physically isolated from copper cabling

- Cables entering or exiting the cable tray must be protected with cable waterfalls
- The signal ground bar must be electrically isolated from other metal
- No. 6 wire with lugs to connect from the ground bar to the rack ground must be used
- 120/208 V_{AC} and 24/48 V_{DC} distribution cable must be in conduit with junction boxes placed above each cabinet location
- Flex conduit must connect the junction box to the rack
- Cable trays in publicly accessible areas must be completely enclosed with tamper resistant tops

Where conditions are not known during design, cable routing Designs must indicate areas for conduit runs and standardized labeling requirements. This will provide a level of instruction to keep the conduits organized to specific locations but give the installers flexibility on how to route the conduits and place the junction boxes based on the site conditions. The final conduit routing must be verified on-site by the Engineer and recorded in the record drawings.

8.5.3 Fibre Distribution Housings (FDH)

To deal with future GPON architecture, the Designer must include a typical layout for how powered fiber would be incorporated into a FDH in a platform marshalling cabinet. FDH must be included in the Design within facilities where required.

8.5.4 Cable Toxicity Requirements

Project specifications must include toxicity requirements for cables on a case-by-case basis where the cable toxicity requirements are application specific.

All cables must have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested to UL 723.

Common cable type designations for low toxicity cables are as follows:

- Low-Smoke, Zero-Halogens (LSZH)
- CMP FT6 plenum rated cables with a low smoke FEP (fluorinated ethylene propylene)

The Boeing BSS7239 smoke toxicity test procedure is a test that requires:

- Carbon Monoxide (CO) < 3500 ppm
- Carbon Dioxide (CO_2) < 90000 ppm
- Hydrogen Fluoride (HF) < 200 ppm
- Nitrogen Dioxide (NO_2) < 100 ppm
- Hydrogen Chloride (HCl) < 500 ppm
- Hydrogen Cyanide (HCN) < 150 ppm
- Sulfur Dioxide (SO_2) < 100 ppm
- Hydrogen Bromide (HBr) < 100 ppm

8.5.5 Data and Telephone Copper Cables

8.5.5.1 Minimum Requirements

Copper cables must conform to the following:

- Conductors must be 22 AWG or larger, tinned copper, meeting Canadian Electrical Code (CEC) for the intended application

- Conductors and cable inner/outer jacketing must be insulated with Polyethylene (PE), Polyolefin (XLPO), or Cross-linked Polyethylene (XLPE or UL type XHHW-2) meeting the following minimum requirements:
  - Sunlight resistant
  - Flame test rated FT4
  - CSA cold impact/bend test at -40°C
  - Suitable for direct burial
  - Rated for wet/dry environments with temperature range from -40°C to +70°C
- Cables must meet all other requirements of direct burial outside plant cables as listed by ICEA S-87-640 [88] for the intended application (i.e. control wiring, telephony, or broadband
- Cables exposed or installed aerially must be rated for installations to -40°C
- A 15 m service loop must be placed in manholes approximately every 300 m and at each cable end
- Cables must be labeled with cable ID at each cable end, in each pull box, and in each manhole
- Cable must not be spliced in manholes. If a splice is required, a pad or pole mounted cabinet must be installed a minimum of 150 mm above ground level or flood level, whichever is higher
- All outside plant copper cables must be terminated within 15 m of the building entrance
- Cable armor, or shields, must be grounded at a single end to achieve single-ended grounding typically on the north or west end of the cable to prevent ground loops

8.5.5.2 CAT6 Copper Cables
All horizontal data and voice cables must meet or exceed CAT6 standards as per ANSI/TIA-568-D [89].

8.5.5.3 Multi-Pair CAT3 Copper Cables
Multi-pair copper voice/analog cables must meet or exceed CAT3 standards as per ANSI/TIA-568-D [89] with the following requirements:

- Conductors must be25-pair 24 AWG solid copper conductors
- Cable groups must be formed into binder groups of 4 pairs
- Insulation must be thermoplastic-covered individuals; riser-rated overall jacket, complying with requirements of CEC
- Each conductor must be colour coded in accordance with industry standard colour scheme for 25-pair, 50-pair, 100-pair, and 200-pair cables
- Each conductor tracer must be coloured in accordance with the corresponding conductor
- DC resistance must be a maximum of 94 Ω /km
- Mutual capacitance must be a maximum of 262 pF/ 100 m @ 1 MHz
- Characteristic impedance must be 100 Ω ± 15%
- Maximum attenuation must be:
- 2.2 dB/100 m @ 772 kHz
- 2.6 dB/100 m @ 1 MHz
- Near end crosstalk coupling loss between pairs within a 25-pair binder group must be greater than or equal to 171 dB @ 1 km @ 1510 kHz and 82 dB @ 1 km @ 10 MHz

8.5.5.4 Multi-Pair CAT3 Outside Plants Copper Cables
All Outside Plant (OSP) copper cabling must meet the requirements listed above for multi-pair CAT3 copper cables.

All OSP copper cabling must have an operational temperature range of -40˚C to +60˚C and an installation temperature range of -20˚C to +60˚C. The cable jacket must be sunlight resistant.

8.5.6 Fibre Optic Cables

8.5.6.1 Outside Plant Fibre Optic Cables

All OSP fibre optic cables must be suitable for installation and operation in underground ducts, cable trays, open air, tunnels, or other areas where uncontrolled temperature and humidity exist and/or where cable may be exposed to water and pest damage. Cable must be a loose tube, gel filled Design having buffer tubes, a central dielectric member (non-metallic), and an aramid yarn outer sheath.

Due to potential placement of outside plant fibre cables adjacent to power conductors, cables must not contain any metal parts, pieces, or attributes.

Fibre cables must meet the requirements of TIA 568-D [89] and GR-20-CORE [129].

Buffer tubes – the optical cable must be a loose tube, gel-filled Design with up to 12 colour-coded fibres contained in loose tubes filled with water blocking gel. The loose buffer tube filling must be an abrasion resistant material while the buffer tube filling must be a homogeneous based gel, dermatologically safe, non-toxic, non-nutritive to fungus, non-hygroscopic, and electrically non-conductive.

Colour code – individual fibres in each buffer tube, and each buffer tube must be colour-coded per EIA/TIA 598-D [130].

Cabling – buffer tubes must be cabled around the central member using either a helical stranding or reverse oscillation method. Fillers should be used to maintain the cable geometry. The interstices between the tubes must be filled with a water blocking gel with the same non-hygroscopic properties used inside the buffer tubes.

Fillers – fillers must be solid polyethylene, or similar material, rods of the same diameter as the buffer tubes.

Central member – the central member that serves as an anti-buckling element must be a glass reinforced plastic rod with a similar coefficient of thermal expansion as the optical fibre.

Tensile strength member – a layer of aramid yarn must be applied over the cabled core in a counter-helical fashion to provide the required tensile strength.

Rip cord – a rip cord of different colour than the aramid yarn must be pulled in longitudinally under both the outer and inner jackets.

Both cable inner and outer jacketing must be insulated with PE, XLPO, or XLPE or UL type XHHW-2 which must meet the following minimum requirements:

- Sunlight resistant
- Suitable for direct burial
- Resistant to fungus growth
- Flame test rated FT4
- CSA cold impact/bend test at -40°C
- Rated for wet/dry environments with temperature range from -40° C to +60° C.
- Free of metal locational or protective elements
- Fibre cable crush resistance per ICEA S-87-640 [88] – 15 kN/m (IEC 60794-1-2 E3) [131]

Table 8.1 Single Mode Fibre Performance Requirements

Single mode fibre must be Corning SMF-28e or equal as follows:	
Fibre Core Diameter	8.2 – 8.8 microns
Fibre Diameter	125 microns +/- 7 microns
Fibre Type	Step index
Cladding Non-Circulatory	≤ 2.0%
Minimum Bend Radius (No load) (Full Load)	 ≥ 10x cable diameter ≥ 20x cable diameter
Attenuation	≤ 0.35 dB/km @ 1285 - 1330 nm ≤ 0.22 dB/km @ 1525 - 1575 nm
Cut-off Wavelength	≤ 1260 nm
Zero Dispersion Wavelength	1310 ≤ Wavelength ≤ 1324 nm
Zero Dispersion Slope	≤ 0.092 ps/(nm^2*km)
Environmental Induced Attenuation For Water Immersion For Humidity Cycling For Temp Dependence	≤ 0.05 dB/km @ 1310, 1550 nm 23°C +/- 2°C - 10°C to +85°C up to 98% RH - 50°C to +85°C
Proof Test Stress	≥ 100 kpsi (0.7 GPa)
Coating Diameter	245 + 5 microns

Cables must meet all other requirements of direct burial outside plant cables as listed by GR-20-CORE [129] and ICEA S-87-640 [88] for the intended application (i.e. control wiring, telephony, or broadband).

Cables exposed or installed aerially must be rated for installations to -40°C.

Outer cable jacket must be marked with the following information (cable print):

- Cable manufacturer
- Number of fibres
- Fibre type (SM or MM)
- LSZH
- Date coded (MMYY)
- Sequential marking (a mark every foot or metre)in a contrasting colour, either black or white, and must be indented into outer jacket

8.5.7 Fibre Cabling, Splicing, and Connectors

All indoor backbone fibre splicing must be housed in a wall mounted Optical Splice Enclosure (OSE) with factory pre-terminated pigtails. All outdoor Fibre Optic Splice Closure (FOSC) fibre splicing must be completed using fusion splicing methods.

Details of all methods for fibre installation and splicing must be documented in the Design.

All proposed cables and connector types for a project must be documented in the Design.

8.6 CLOSED CIRCUIT TELEVISION (CCTV)

The CCTV system allows the Operator's personnel to remotely monitor and record activities at Stations and other designated locations. All CCTV equipment must conform to models currently operated and maintained by the Operator. Refer to Operator's Approved Products List.

8.6.1 CCTV Architecture

The Operator's current CCTV system uses IP-based security cameras, which connect to a CCTV VPRN service and are interfaced to an Owner provided video management system, the Genetec Security Center (GSC). All system additions or modifications must be GSC architecture and no alternate video systems or platforms are permitted.

The GSC system is based on a "Failover/Redundant Centralized" system model. The GSC system is comprised of a fully redundant directory set, the primary management servers for the Universal System Platform (USP), and archivers (video recording servers) configured for redundant recording. These servers, which are all physical, are provided by the Operator's CIE. In addition, there are several sites with on-site archivers that are not connected to the GSC, due to limited WAN bandwidth availability at the time of their deployment. These will be migrated to the CIE storage platform once the WAN bandwidth is increased.

Cameras, encoders, input/output modules (alarm units), and client workstations located throughout the Operator's facilities are connected to the CCTV network via local switches connected to the Operator's fibre network backbone. This network is used to connect all field devices with the Genetec servers (directories and archivers) for transport of video and other data.

In addition to the GSC Video Management System (VMS), the Operator uses a centralized device management platform for all CCTV field devices, such as cameras, encoders and input/output modules. This software allows an interface through which device status can be verified, firmware updates can be applied, and global programming configuration changes can be deployed. This management software is provided by the hardware manufacturer and does not allow for devices from disparate manufacturers. The Operator has standardized on the use of Axis Communications as the supplier for all cameras, video encoders and input/output modules.

8.6.2 Site Coverage.

Camera placement, as described herein, must provide sufficient detail to clearly identify individuals and objects within the required fields-of-view. The actual resolution and pixels-on-target vary, depending on the specific location. PTZ cameras are used to allow for closer inspection of areas of interest, which may reduce the overall number of fixed cameras in a given coverage area. Camera placement must capture relevant details of the location taking into consideration that a train may be blocking the field of view. In such cases, extra cameras, pole mounting, or setback to achieve a wider view and PTZ camera functionality may be required.

8.6.2.1 Security Surveillance

Camera coverage is required for security sensitive areas. Refer to Chapter 15, Safety and Security.

8.6.2.2 Operations Surveillance

The Operator has designated certain operational areas to have coverage and visibility through the CCTV system.

- During peak hour and special events, the Operator must be able to use camera views to observe passenger occupancy and boarding conditions at selected stations to determine if additional trains are required.
- PA/VMS Signs on platforms must be clearly visible over the entire sign face via a PTZ camera, including a view of each side of double-faced signs, where applicable.
- Clock tower and parking lot signs must be visible via a PTZ camera.
- Designated Operator employee access doors or entrances must have CCTV coverage.
- CCTV coverage for both access locations and inner areas must be provided for traction power substations, communications rooms, and signals rooms.
- All At-Grade crossings in the LRT System must be covered with a fixed view camera to allow monitoring of pedestrians, cyclists, motor vehicles, and crossing arm position to assist with post-incident investigations. Multiple cameras or multisensor camera devices may be required to provide sufficient viewing detail.

8.6.3 Lighting/Illumination

New lighting installations must not require additions or modifications to the lighting in place, unless otherwise provided for under a renovation or remodeling project. If a CCTV camera is located in a room or location where there is zero-light condition, the Designer may be required to providing dedicated lighting such as infrared or white-light LED illuminators. These illuminators must be designed to operate with the specified camera type for the specific location and must be selected according to the size and configuration of the area to be viewed.

8.6.4 Closed Circuit Television Cameras

CCTV cameras must be current technology in design and construction. They must be IP based, totally self-contained, high resolution, colour, solid state units with true day/night functionality, designed for any mounting position complete with all necessary attachments to suit their application.

8.6.4.1 Closed Circuit Television Camera and Enclosure Standards

CCTV Cameras and enclosures must meet the following standards and requirements:

- Product safety standards as defined in IEC/EN/UL 60950-1 [69]
- Product safety standards as defined in IEC/EN/UL 60950-22 [72]
- Relevant parts of SMPTE 296M (HDTV 720p) [132]
- Relevant parts of SMPTE 274M (HDTV 1080p) [133]
- ISO/IEC 14496-10 MPEG-4 part 10, advanced video coding (H.264) [134]
- ONVIF profile S [135] or ONVIF version 1.01 [136] or higher as defined by the ONVIF organization
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- EMC approvals:
  - EN 55022 Class B [137]
  - EN 55024 [138]
  - FCC Part 15 - Subpart B Class A + B [139]
  - VCCI Class B [140]
  - RCM AS/NZS
  - CISPR 22 Class B
  - ICES-003 Class B [141]
  - KCC KN32 Class B
  - KN35
  - KCC KN22 Class B

- KN24

- Mechanical and environmental standards:
  - IEC/EN 60529 [78]
  - IP66/67 [118]
  - ISO 20653 [119]
  - IP6K9K [120]
  - NEMA 250 Type 4X [121]
  - IEC/EN 62262 IK10 [122]
  - IEC 60068-2-1 [123]
  - IEC 60068-2-2 [124]
  - IEC 60068-2-6 [125]
  - IEC 60068-2-14 [126]
  - IEC 60068-2-27 [127]
  - IEC 60068-2-78 [128]

- Railway environmental standards:
  - EN 50121-4 [66]
  - IEC 62236-4 [68]

- IEEE standards:
  - 802.3af/802.3at (Power over Ethernet) [142]
  - 802.1X (Authentication) [143]

- Internet Engineering Task Force (IETF):
  - IPv4 (RFC 791) [113]
  - IPv6 (RFC 2460) [114]
  - QoS – DiffServ (RFC 2475) [115]

- Camera cases must be IP66, IP67, IP6K9K, and/or NEMA 4X-rated, IK10 impact-resistant, with polycarbonate dome, aluminum base and dehumidifying membrane
- Operating temperature range must be -40°C to +60°C
- Operating humidity range must be 10-100% RH (condensing)
- Manufactured in accordance with ISO 14001 [144]
- Compliant with the EU directives 2011/65/EU (RoHS) [145]and 2012/19/EU (WEEE) [146]
- Compliant with the EU regulation 1907/2006 (REACH) [147]
- PVC-free in accordance with IEC 61249-2-21 [148]
- Must have a Communication on Progress (CoP) document signed by the manufacturer committing to support the UN Global Compact initiative

8.6.4.2 Sensors & Optics

Cameras must be equipped with an IR-sensitive progressive scan sensor and must contain a removable IR-cut filter providing day/night functionality.

Cameras must meet or exceed the following illumination specifications:

- 0.15 lux at 50 IRE F1.6 (colour)
- 0.04 lux at 50 IRE F1.6 (B/W)

8.6.4.3 Camera Lenses

All cameras must have factory-installed lenses/optics which have been designed to function correctly with the devices including all necessary feature support.

Where applicable, lens options, including specific focal-lengths, must be selected in the Design to meet the installation and field-of-view requirements. After-market lenses or optics must not be used on new cameras.

8.6.4.4 Pan/Tilt/Zoom Functions

PTZ cameras must have the following features:

- The camera must include more than 255 manually set preset positions.
- The camera must provide e-flip functionality, which will automatically rotate the image 180° electronically when following a moving object passing under the camera.
- The camera must provide a guard tour functionality, which allows the dome to automatically move between selected presets using an individual speed and viewing time for each preset.
- The camera must be able to record a custom PTZ tour, operated using an input device such as a joystick, mouse, or keyboard, and then use and recall this as a guard tour.
- The camera must detect and automatically follow moving objects in the camera's field of view.
- The camera must provide On-Screen Directional Indicator (OSDI) functionality.
- The camera must be equipped with accurate high-speed pan-tilt functionality with 360° endless pan range and a 180° tilt range.
- The camera must provide pan and tilt speed between 0.05°/sec and 450°/sec.
- The camera must include 32x optical zoom and 12x digital zoom with adjustable zoom speed.

All PTZ cameras must be integrated dome cameras. The camera dome drive system must consist of a discreet, miniature camera dome, a variable speed (high speed) pan and tilt drive unit with continuous 360° rotation, optical and digital zoom, auto focusing, motorized zoom lens, and an integral receiver.

Cameras must have variable speed capabilities ranging from a smooth, fast pan motion of 360° per second to a smooth "creep" speed of 0.1° per second and be capable of 360° rotation with an "e-flip" feature that allows the dome to rotate 180° and reposition itself for uninterrupted viewing of any subject that passes directly beneath the dome.

Dome back boxes must include built-in memory to store camera and location specific dome settings, including labels, presets, patterns, and zones. These settings are automatically downloaded when a dome is replaced.

Domes must contain on-screen, user-defined programmable patterns that include pan, tilt, zoom, and preset functions.

Domes must be individually programmable to initiate a stored pattern, or to go to an associated pre-set when an alarm is received. Following the alarm acknowledgement, the dome must return to a previously programmed state or to its previous position before the alarm was activated.

The dome must incorporate independent automatic colour to black and white switching modes for automatic switchover from colour in daytime, to high sensitivity black and white at night.

8.6.4.5 Image Control

The following image control features must be provided:

- The unit must have automatic and manual white balance

- The camera must provide up to120 dB dynamic range
- The camera must have an electronic shutter operating at minimum in the range of 1/100,000 s to 2 s
- The camera must incorporate Highlight Compensation (HLC) and Backlight Compensation (BLC)
- The camera must provide a function for optimization of low light behavior

8.6.4.6 Video

The following video features must be provided:

- The camera must provide simultaneous motion JPEG and H.264 video streams.
- The camera must be designed to provide at least two video streams in HDTV 1080p (1920x1080) at up to 30 frames per second (60 Hz mode) or 25 frames per second (50 Hz mode) using H.264 or motion JPEG.
- The camera must be designed to provide at least two video streams in HDTV 720p (1280x720) at up to 60 frames per second (60 Hz mode) or 50 frames per second (50 Hz mode) using H.264 or motion JPEG.
- The camera must support H.264 baseline, main and high profile.
- The H.264 implementation must include both unicast and multicast functionality and support Maximum Bit Rate (MBR) as well as Variable Bit Rate (VBR).
- The camera must support H.264 automatic scene adaptive bitrate control with automatic dynamic ROI (Region of Interest) encoding that will reduce bitrate in unprioritized regions and will lower overall bandwidth and storage requirements.

8.6.4.7 Storage

The following storage features must be provided:

- The camera must be equipped with a video buffer for saving pre- and post-alarm images and must have an SD card slot to support local storage of video.
- SD cards must be ruggedized industrial storage cards with a minimum of 21 days of video storage and conform to models currently operated and maintained by the Operator.
- The camera must support recording to network attached storage.

8.6.4.8 Connectors and Connectivity

Cameras must be connected to the communications network with one of the following options:

- RJ45 100BASE-TX/1000BASE-T PoE ethernet port connected to a network switch.
- RJ45 100BASE-TX/1000BASE-T PoE ethernet port interfaced to a powered fibre media converter.
- Single mode fibre combined with -57VDC on copper conductors in a hybrid cable for powered fibre connection.

8.6.4.9 Power

The following power features must be provided:

- CCTV devices must be powered by uninterruptable, high availability power, supplied by the Operator’s CADPM power system.
- Cameras must be connected to fibre either directly or using a media converter and powered by PoE supplied by the network switch, a PoE midspan, or directly by powered fibre architecture, through single mode fibre, SFP module and two-conductor -57VDC power in a hybrid fibre cable.

8.6.4.10 Camera Mounts

The following camera mount features must be provided:

- Camera mounts must be designed specifically for use with the prescribed cameras.
- Placement of camera mounts must allow the camera to provide the view required by the Operator, while considering maintenance requirements.
- Mounting brackets must be compatible with the poles or structures used at a location including ceiling mounts, wall mounts, corner mounts, pole mounts, and parapet mounts.

8.6.4.11 Camera Poles

For pole-mounted cameras, dedicated camera mounting poles must meet the following requirements:

- Camera poles must have a square section measuring a minimum of 4.75 in x 4.75 in. (120 mm x 120 mm)
- Total camera pole height including the pole base must be 18 ft. (5.5 m)
- The camera pole mounting base must be a minimum of 13 in x 13 in (330 mm x 330 mm).
- Camera poles must be constructed from extruded aluminum with powder coat finish.
- Camera poles must mount directly onto a NEMA 4 rated base box measuring 15 in x 18 in x 22.5 in (381 mm x 457 mm x 572 mm)
- Where practicable, the camera pole should include an internal camera lowering mechanism.
- Camera poles must include one internal CAT6 cable preinstalled by the manufacturer to accommodate connection of the camera to the base of pole while allowing necessary cable retraction during lowering.
- Where a single pole is used for mounting two devices, the manufacturer's applicable dual-mount adapter must be used. For existing fixed poles this may be a separate mounting accessory. Where a lowering mechanism is used, the pole must be a dual-mount model, and include a dual mounting adapter and two internal CAT6 cables.
- Camera poles must be equipped with the manufacturer’s lightning rod and anchoring jig.
- Camera Poles must conform to models currently operated and maintained by the Operator. See Operator’s Approved Products List for further details.

8.6.4.12 Camera Security

The following camera security requirements must be met:

- To secure access to cameras and provided content, the unit must support HTTPS, SSL/TLS and IEEE802.1X authentication.
- The camera must provide centralized certificate management, with both pre-installed CA certificates and the ability to upload additional CA certificates. The certificates must be signed by an organization providing digital trust services.
- The camera must support IP address filtering and include at least three different levels of password security.

8.6.4.13 Application Programmers Interface and Applications

The following Application Programmers Interface (API) and Applications requirements must be met:

- The camera must contain a built-in web server making video, audio, and configuration available in a standard browser environment using HTTP(S).
- The camera must be fully supported by an open and published API providing necessary information for integration of functionality into third party applications.
- Cameras must comply with relevant ONVIF profiles as defined by the ONVIF Organization Network functionality.

8.6.4.14 Camera Network Functionality

The following network functionality must be provided:

- The camera must support both static IP addresses and addresses from a DHCP-server
- The camera must support both IPv4 and IPv6
- The camera must incorporate support for Quality of Service (QoS)
- The camera must incorporate support for Bonjour

8.6.4.15 Camera Audio

The camera must support two-way full duplex audio as follows:

- Input sources: external microphone (balanced/unbalanced) or external line device
- Output sources: external line device
- AAC LC audio encoding at 8/16 kHz
- G.711 PCM audio encoding at 8 kHz
- G.726 ADPCM audio encoding at 8 kHz

8.6.4.16 Event Functionality

The camera must be equipped with integrated event functionality, which can be triggered by:

- Video motion detection
- Audio detection
- Live stream accessed
- Manual trigger/virtual inputs
- Fan malfunctioning
- PTZ functionality
- External input
- Embedded third party applications
- Edge storage disruption detection
- Shock detected

The camera response to a triggered event must include:

- Send notification, using HTTP, HTTPS, TCP, SNMP trap or email
- Send images, using FTP, HTTP, HTTPS, network share or email
- Send video clip, using FTP, HTTP, HTTPS, network share or email
- Recording to local storage and/or network attached storage
- Activating external output
- Day/night vision mode
- Play audio clip
- PTZ control functionality
- Overlay text

8.6.4.17 Additional Functionality

The following additional camera functions are required:

- The camera must provide text overlay ability, including date and time.
- The camera must have the ability to apply a graphical image as an overlay image in the video stream.
- The camera must have the ability to provide up to 32 individual 3D privacy masks to the image.

- The camera must include a customizable pixel counter functionality, identifying the size of objects in number of pixels.
- The camera must allow updates of the software (firmware) over the network, using FTP or HTTP.
- The camera must support time synchronization via NTP server.
- The camera must provide a log file, containing information about all users connecting to the unit since last restart. The file must include information about connecting IP address and the time of connecting.
- The camera must be monitored by watchdog functionality, which must automatically re-initiate processes or restart the unit if a malfunction is detected.
- The camera must send a notification when the unit has re-booted, and all services are initialized.

8.6.4.18 Fixed Camera Type 1

Type 1 cameras must be used in locations where lighting is uncontrolled and lighting conditions may be extremely poor. Cameras that are exposed to a wide range of lighting conditions must adjust dynamically from very bright to very low light levels. These cameras must be suitable for installation either indoors or outdoors without requiring the addition of accessories beyond those which may be required for mounting or cabling.

Type 1 cameras must provide the ability for post-installation adjustment of the field-of-view through remote adjustment of the camera's optical head allowing modification of the pan, tilt, and rotation as well as the zoom level of the lens. The camera must support recording to network attached storage. Fixed Type 1 cameras must conform to models currently operated and maintained by the Operator.

8.6.4.19 Fixed Camera Type 2

Type 2 cameras may be used in locations where lighting is evenly controlled, and lighting conditions are consistent. Cameras may still be exposed to extremely bright light or glare and must adjust dynamically to these conditions. Type 2 cameras are not required to offer the same sensitivity levels for low light conditions as Type 1 cameras. Type 2 cameras must be suitable for use outdoors or where they may be exposed to the elements, temperature fluctuations, or moisture. The camera must support recording to network attached storage. Fixed Type 2 cameras must conform to models currently operated and maintained by the Operator.

8.6.4.20 PAN/TILT/ZOOM (PTZ) Cameras – Interior Application

Interior unitized PTZ cameras allow for expanded coverage of larger areas and provide tracking options during critical events. In areas where the camera will not be subjected to temperatures below 0° C or high moisture levels, a PTZ camera may be an interior rated device. PTZ interior cameras must conform to models currently operated and maintained by the Operator.

8.6.4.21 PAN/TILT/ZOOM (PTZ) Cameras – Exterior Application

Exterior unitized PTZ cameras allow for expanded coverage of larger areas and to provide tracking options during critical events. Exterior PTZ camera must operate in a temperature range of -40° C to 50° C, with a maximum intermittent temperature of 60° C. The camera must be equipped with arctic temperature control, allowing camera start-up at temperatures as low as -40° C and be environmentally rated. The camera must operate in a humidity range of 10 to 100% RH (condensing). PTZ exterior cameras must conform to models currently operated and maintained by the Operator.

8.6.4.22 Multisensor Cameras

Multisensor cameras provide multiple views of a location from a single camera device. Multisensor cameras must conform to models currently operated and maintained by the Operator.

8.6.4.23 Specialized Application Cameras

The Operator maintains an approved list of cameras for specialized applications, such as when a 180° field of view is required or when video analytics will be deployed. Refer to the Operator's Approved Products List.

8.6.4.24 Alarm Interface Device

Alarm interface devices provide an interface between external dry contact "alarm points" and the Genetec security system. All alarm-point connections must be to an alarm interface device.

There are several different alarms that are passed to the Genetec security system. They are initiated by alarm contact closures installed in the following:

- Help phone activation
- Panic alarm activation
- TVM (ticket vending machine) door opening
- Smartfare Vending Machines (SFVM) door opening
- Service door opening

Once a contact is triggered on an alarm unit, the GSC system causes a camera to move to the location of the alarm and bring up the video in the OCC.

Alarm Interface Devices must conform to models currently operated and maintained by the Operator.

8.7 PUBLIC ADDRESS/VARIABLE MESSAGE SIGNS (PA/VMS)

The PA/VMS consists of the PA system, which provides both automated train arrival announcements and allows the Operator to make public announcements in all LRT Stations and Transit Centres, and the VMS system, which displays Passenger information messages on electronic signs at Platforms, clock towers and parking lots.

The PA/VMS system must be compatible with and interface to the existing Signalling and Train control system and the communications network.

PA/VMS equipment must conform to models currently operated and maintained by the Operator.

8.7.1 Public Address System

All Stations and Platforms are equipped with amplified Public Address (PA)voice messaging systems. Stations have loudspeakers on the Platform and on Concourse levels. Several Stations also have loudspeaker coverage in connecting public pedways, as well as landing levels.

Loudspeakers operate in a zoned manner to allow individual area announcements, as well as multi-zones and "All-Call" general announcements. The audio-acoustic quality of announcements must be clear, intelligible, and easy to understand.

8.7.1.1 Location Considerations

Loudspeaker placement must include Platforms, Concourses, and connecting pedways. Configuration of loudspeaker zones will vary according to architectural design. Speaker type and placement must minimize the sound spill of amplified messages into adjacent private property. At a minimum, the public address system must comply with the noise provisions of the City of Edmonton Community Standards Bylaw 14600 [79].

8.7.1.2 Acoustic Conditions and Treatment

PA infrastructure must deliver high speech intelligibility, even when operating in a reverberant and raised ambient noise environment.

Station materials and finishes must be coordinated with the Station Designer to limit acoustic reflection and complement the goal of maximizing PA system performance. The RT60, defined as the time it takes sound pressure to be reduced by 60 dB after the sound stops, should be less than 1 second. If the RT60 is more than 1 second, computerized models, such as Enhanced Acoustic Simulator for Engineers (EASE) by AFMG, must be used to determine optimal speaker locations and acoustic treatments to achieve intelligible messaging.

8.7.1.3 System Acoustic Performance

Loudspeakers must be placed to provide consistent and uniform sound levels throughout designated speaker zones. The following acoustic performance levels must be met:

- Sound levels must be 6 to 10 dB above ambient noise levels to assure a high degree of speech intelligibility.
- Typical ambient Sound Pressure Levels (SPL) must be 75 dB (+/- 2 dB) at 1.2 m above floor level.
- The PA system must meet the noise provisions of the Community Standards Bylaw [79].
- Reverb level at Platform, concourse, and pedway locations should be less than 1.0 s at 500 Hz.
- The PA system must provide adequate dynamic range and system gain to ensure intelligible speech.
- Overall system hum and noise must be lower than –70 dBm.
- Harmonic distortion must be less than 2% measured at stated operating SPL and specified frequency response.
- PA system frequency response must be uniform to +/- 2 dB from 200 Hz to 6000 Hz, measured with a 1/3 octave broadband signal.
- The PA system must provide automatic gain and compression features to assure speech levels from loudspeakers to public areas remain constant within 2 dB SPL.
- The overall minimum performance value for the PA system must be 0.55 or better on a Speech Transmission Index (STI) scale.

8.7.1.4 Loudspeakers and Placement

The technical performance characteristics, and architectural/mounting features of loudspeakers must match the acoustic conditions and treatment of the PA zone.

Sound should project from one direction only. The Design must not locate speakers in ceilings and on walls in the same area. Speakers on walls must not be directed toward each other.

The Design must provide directional dispersion speakers, with tight pattern control, in a distributed overhead loudspeaker configuration. Sound should not reflect from room walls. Loudspeaker spacing must satisfy the requirement for no dead spots or SPL variance of more than 2 dB.

Weatherproof loudspeakers and mounting fixtures must be provided for all outdoor locations. Outdoor loudspeaker direction must minimize any significant sound spill to adjacent private property.

Speakers must be placed at a minimum height of 3050 mm above a Platform and fitted with vandal resistant housing and hardware. Speakers must be tapped at 5 W.

PA automatic volume control systems should be considered in Stations, with the volume control system able to automatically compensate for high wind or a high background noise environment.

Designs should consider using IP speakers where practicable.

8.7.1.5 Amplifiers

Amplifiers are required to provide suitable acoustic performance and SPL for intelligible voice announcements, as described in Section 8.9.2.3.

Audio amplifiers must have the following features:

- Meet professional technical performance specifications
- Provide overload protection and convection cooling only
- Have a power rating suitable for individual loudspeaker zones
- Provide integrated 70 V constant line operation
- Have the ability to monitor the health of all connected speaker zones
- Include integrated Digital Signal Processing (DSP) and ambient noise sensing functions
- Include the integrated ability to play out messages
- Be network connected, remotely manageable and configurable
- Be connected to a central backend system that monitors all amplifiers on the system

The total number of amplifier output channels must equal or exceed the number of logical zones within the Station.

The loudspeaker circuit loading must be designed with a minimum 20% power margin. The amplifier power distribution must be a 70 V constant current method.

8.7.1.6 Signal Processing

To provide speech clarity in all loudspeaker areas, professional grade DSP with full audio spectrum tuning ability must be provided. Electronic audio signal processing must include automatic signal compression and limiting features to provide consistent voice levels throughout loudspeaker areas.

The Design should include the capability to tune audio performance using pink noise and 1/3-octave equalizers.

8.7.1.7 Conduit and Wiring

All PA wire, cable, and connectors must be run in electrical conduit, junction boxes and backboxes. Maximum length of flex conduit must be 1 m.

Distributed loudspeaker wiring cable must be no less than #18 AWG. Audio cable must be twisted pair, complete with 100% shielding and grounded only at an equipment cabinet.

Low level audio signal cables must not run in the same conduit as high level audio loudspeaker cables.

All cable connections must be made on approved clamp terminal wiring blocks. Field wiring to tie together multiple speaker zones must be accomplished on terminal blocks, not on the terminal screws of the amplifier.

8.7.1.8 Microphones

All microphones must interface with the PA system and must be PoE powered IP microphones. These devices must integrate directly with the PA system and be monitored and configured from a central system the same as the amplifiers.

8.7.1.9 Integration of Public Address System to the Telephone System

The PA system must interface to the Operator's telephone system, so that announcements can be made at Stations and various other locations using the telephone system. The PA/VMS has a SIP registration to the Cisco Unified Communication Manager (CUCM) system.

8.7.2 Variable Message Signs

8.7.2.1 Variable Message Signs

Variable Message Signs (VMS) provide Train arrival times, public information relevant to the LRT including service outages, public newsfeeds such as weather information, and operational status of the LRT elevators, and escalators.

8.7.2.2 Installation Guidelines

The following VMS installation guidelines must be followed:

- No overhead single sided signs on Platform areas are permitted (unless mounted to a wall).
- Outdoor signs must be under a rain shield.
- All signs must be visible to a camera on both sides (note that PTZ cameras cannot look upward from their mounting height).
- VMS signs should not be in line with Wayfinding signs as they block sight lines for each other.
- VMS signs must be below and at least 2 m from the Overhead Contact System (OCS) to allow maintenance personnel to access them without a TP shutdown, unless a physical barrier exists
- Sign placement must permit Patrons to see a VMS sign from all areas of the Platform.
- VMS signs must be visible to Patrons entering a Platform.
- Signs must be mounted high enough that Patrons can not touch them.
- All enclosures must be NEMA-4 or better using water and dust resistant gaskets and water-tight connectors for wiring and be able to withstand power washing without water ingress.
- Conduits or connections which run to VMS signs but originate from a high moisture area (e.g. under a Platform or other unheated or unconditioned space) must be sealed after installation.
- VMS signs must be on BMS controlled power circuits for remote power cycling.

8.7.2.3 Connectivity

VMS must be IP-based and connected to the Operator's CIE with CAT6 or powered fibre.

8.7.2.4 Electrical Power

All VMS equipment must be powered by conditioned UPS back up power or generator emergency power and must be on the same phase. Confirmation must be obtained from the Engineer and the Operator whether VMS signs will be powered by UPS power or generator emergency power.

VMS power must be fed through the low voltage lighting relay cabinet to be able to be cycled by BMS.

8.8 TELEPHONE SYSTEMS

Telephone systems for the LRT System are classified as follows:

Phones available for public use:

- Information phones
- Emergency phones
- Elevator phones
- Washroom access phones

Phones available for the Operator's use:

- ROW phones
- Staff service phones
- Equipment room phones
- OCC phones

Other phone connections on copper and wireless telephone company services:

- Fire Alarm System (FAS) auto-dialers

Telephone systems provide emergency and non-emergency voice communications for all LRT facilities.

The telephone system uses a CUCM System. Cisco VoIP phones are located in the LRT OCC and each Station is equipped with Cisco phones. The CUCM system must manage all the phones for different services. Each phone must connect directly to the fibre backbone through backbone switches in the nearest communications room. For Public Switched Telephone Network (PSTN) calls, the service provider will establish an interface connection with the Operator's VoIP server.

VoIP phones can be monitored for device status and can be configured with calling features by the CUCM system. Additionally, all phone calls handled by the LRT OCC will be recorded and archived in the Operator's CIE voice logging servers.

Phone equipment and VoIP software must conform to models currently operated and maintained by the Operator. Refer to the Operator's Approved Products List.

8.8.1 Automated Device Testing

All emergency phones, information phones and security phones must be automatically tested through a remote test of a phone's network connection, call button and/or off-hook switch.

8.8.2 Right of Way (ROW) Phones

ROW phones must be installed at nominal 350 m intervals along the LRT Corridor and connected to cables and vaults that are part of the LRT communications infrastructure. VoIP ROW phones should be used wherever practicable. For signal bungalows, these will be mounted on the outside of the bungalow. ROW phones are mounted on poles specifically for ROW phones along the right of way. ROW phones must use 2-pair hybrid fibre optic cable to connect each ROW phone to the communications network and 57 Vdc power.

ROW phones must also be installed at each end of all LRT platforms.

ROW phones must also be installed at each grade crossing location, at tunnel portals, in tunnels, and at each tunnel cross-connection. A blue light must be installed at these tunnel phone locations.

ROW phones must be heavy duty, weather-proof, and have an armored handset cord.

If a ROW phone call is made to the LRT OCC, the call is recorded. If the ROW phone call is to another ROW phone, the call is not recorded. Dialing to a number outside the LRT network is blocked.

8.8.3 Fire Alarm System Auto-Dialers

FAS auto-dialers must be installed at building fire alarm panels.

Each Utility Complex will require both a land line (copper analog line) and a cellular back up line for transmission of signals from the building fire alarm panel. Designers must allow adequate space in the local telecom service provider room for an entrance cable isolator from Telus. For example, where the FAS circuit must be installed in a stand-alone Traction Power Substation (TPSS), it may be more practicable to locate the demarcation point outside the substation to minimize the footprint of the telecom isolator.

Alarm and trouble supervisory conditions must be sent to a ULC approved Fire Signal Receiving Centre (FRSC). This is a code requirement to meet CAN/ULC-S527 [149] and CAN/ULC-S559 [150]for primary signal transmission compliance. Also, the fire alarm and trouble signals must be simultaneously sent to the LRT OCC. Refer to Chapter 12, Mechanical for additional details.

Refer to Facility Engineering Services - Facility Planning & Design - Facility Infrastructure & Delivery Consultant Manual - Volume 2 -Technical Guidelines, Section 2.8 and Appendix F.

8.8.4 Emergency Phones

Emergency help phones must be located as follows:

- On Station Platforms next to entry/exit points, next to information panels, in elevators, and near seating areas
- On Station Concourse levels in fare paid areas near to information panels and fare equipment
- In LRT parking lots and structures

All emergency phones must activate an alarm in the CCTV system when a call is placed. This alarmmust trigger the CCTV system to move the closest PTZ cameras to focus on the emergency help phone causing the alarm and display that camera view in the main control room, so the Operator has visual awareness of the emergency. Emergency phones are programmed as an auto ring down telephone line to the Operator’s LRT OCC.

8.8.5 Elevator Help Phones

Elevator help phones will be provided by the elevator company and will be interfaced with the LRT OCC using an auto ring-down connection.

8.8.6 Washroom Access Phones

Washroom access phones must be installed at Stations where washroom facilities are available to the public. Washroom access phones are programmed as an auto-ring down connection to the LRT OCC. Public washroom locks are controlled through a phone system interface. Refer to the Operator's BCP for Washroom Access Phones.

8.8.7 Staff Service Phones

One single line telephone must be provided and installed in all service rooms in Stations and Ancillary Facilities where access is required by service and maintenance personnel. These phones are programmed for local calls only.

8.8.8 Information Phones

Information phones must be located next to or built into information panels located on Platforms and Concourse levels. Information phone calls are an auto ring-down line to “311” and are answered by a City of Edmonton 311 operator.

8.8.9 Signage, Call Recording, and Caller-ID

8.8.9.1 Signage

Signage for information phones, emergency phones, elevator help phones, and washroom access phones must also be provided in braille for visually impaired or blind Patrons. Signage for phones must conform to current signage on the LRT System.

8.8.9.2 Call Recording

All calls to and from the LRT OCC are recorded.

The current standard for voice logging is NICE. All radios and VoIP telephones are recorded by NICE.

8.8.9.3 Caller-ID and Directory Number Conventions

Caller-IDs and Directory Numbers must use the Operator's conventions. Refer to Operator's Caller ID and Directory Number BCP.

8.9 RADIO SYSTEMS

Radio equipment must conform to models currently operated and maintained by the Operator.

The LRT System currently shares a radio system with the Alberta First Responders Radio Communications System (AFRRCS). This system operates with frequencies in the 700 MHz range and is based on the APCO P25 standard.

Radio coverage in LRT tunnels is currently provided by radiax cables which are installed in the tunnels and designed to effectively cover the tunnel space. As well, the system is fibre fed from two donor locations for reliability and the cleanest signal possible.

Control features and operating software of any future system must be compatible with P25 radio systems technology and equipment and must be forward compatible with new wireless network technologies.

Powering for radio base station equipment must be supplied by a radio battery plant, typically the Operator’s CADPM (Communications AC and DC Power Module). Refer to CADPM Design Services Document (DSD).

8.9.1 Portable Radios

Portable radios must meet TIA-102 (APCO P25) standards and must be on the Government of Alberta (GoA) approved device list for AFRRCS.

Portable radios must meet Operator size and weight requirements. Lithium chemistry batteries must be used for maximum battery life and light weight. NiMH, NiCad, and lead acid batteries are not permitted.

8.9.2 Mobile Radios

Mobile radios must meet TIA-102 (APCO P25) standards and must be listed on the GoA approved device list for AFRRCS.

Mobile radios must include provisions for mounting brackets and power connections to the Operator's vehicles including LRVs, rail maintenance vehicles, cars, and trucks.

8.9.3 Distributed Antenna System

The Distributed Antenna System (DAS) must use a hybrid fibre and coax infrastructure solution designed in a redundant configuration. The DAS receives RF signals from the base station and distributes the RF signal to antennas over either coaxial cable (passive DAS) or fibre (active DAS).

With passive DAS, coaxial cable and other passive components, splitters and couplers are used.

Active DAS provides improved installation and maintenance benefits over passive DAS, but may have limited range and increased system noise. Active DAS should be used for in-building wireless installations for large facilities.

The Operator's DAS has the following requirements:

- DAS system must be compatible with all major access protocols used worldwide including GPRS, EDGE, CDMA2000, 1xRTT and W-CDMA, LTE., LTE-U.
- DAS must cover a minimum RF frequency range of 700 MHz to 1900 MHz.
- DAS must include software configurable frequency configuration, system gain and RAU output power.
- DAS must support industry standard cabling options.
- DAS must support modular and scalable system equipment.
- DAS must be deployable in environments with potentially high levels of RF interference. while maintaining acceptable levels of operational reliability.
- DAS must not require separate power connections to the unit's antennas.
- DAS must be CUL and CSA approved.
- The installed DAS must not interfere with the Operator's equipment and operations or with any other existing RF systems on the LRT System and must provide signal coverage of 95% or better in public and non-public areas inside Stations and inside tunnels.

8.9.4 Radiax Design

The LRT radio system currently uses radiax 'slotted cable' antenna systems. Radiax cable is currently installed in Station structures, Grade Separated structures, pedways, and throughout the length of the underground tunnels. To minimize conflicts with other tunnel electrical and communications systems, radiax is currently mounted on insulated radiax standoff hangers.

8.9.5 Radio Coverage

Current radio coverage provides over 99% reliable communication within 95% of the LRT ROW.

For mobile radios and portable radios, the LRT ROW should maintain a coverage Received Signal Strength Indicator (RSSI) level that allows for 99% reliability in all Train radio communications. This is usually expressed in terms of minimum dBm level expectations in the Transportation Corridor which provides sufficient S/N margins of >15 dB. More specifically, the minimum signal penetration must be as follows (based on 700 MHz operation):

- -85 dBm indoors through 95% of the anticipated coverage area
- -95 dBm outdoors through 90% of the anticipated coverage area
- -95 dBm within the LRT ROW through 95% of the anticipated coverage area

A coverage survey must be undertaken to measure sample points along the Transportation Corridor and other critical coverage areas. Coverage maps must be created to record survey data, coverage estimates where survey data isn't available, and include buildings and underground structures including known future proposed changes to structures and site layouts.

For any new facilities or new radio services, a site acceptance test plan must be prepared which identifies the tests to be done, test conditions, instrumentation to be used, the test locations, performance expectations, pass-fail criteria, and when tests are to be completed. A standard minimum performance should be established over a reasonable time period (e.g. minimum $1x10^{-8}$ BER over a 1-hour test period) to ensure testing validity, accuracy, and reliability.

Radio coverage must adequately serve ground level radio communications for Trains, Stations and Ancillary Facilities. Any Operator location with rooms or accessible areas below ground level must provide active DAS technology, similar to tunnels and underground Platforms.

8.10 SIGNALS NETWORK

8.10.1 Conventions

Signals Room Routers (SRR) and Territory Ring Routers (TRR) are the two types of network switches currently connected to the main Operator Signalling network.

Signals network equipment and software must conform with equipment and software currently operated and maintained by the Operator.

8.10.2 Redundancy

All Signal switches must be connected in a dual layer 2 managed ring that provides redundant failover paths.

8.10.3 Monitoring of Devices

All Signals network devices are currently monitored by the Operator's SNMP network monitoring platform that provides a complete view of all normal operations, failures, and alarms for the Operator's network.

8.10.4 Signals Fibre Backbone

To reduce the likelihood of field disconnection of fibre, the Operator has dedicated buffer tube number 11 in the 144-fibre backbone for the exclusive use of Signals. This buffer tube is currently spliced directly from the backbone into the Signals room and the only location any changes may be made is in the Signals room with the Operator's supervision. Designers must coordinate with the Operator on interfaces and connections to this fibre network.

8.11 TRACTION POWER SUBSTATION NETWORKS

8.11.1 Architecture

The Traction Power Substation (TPSS) communications network currently consists of three separate networks. One is a ring that starts at the Churchill OCC and picks up the five southernmost substations on the Capital line. In addition, Churchill OCC and the entire Metro line are connected to this network. This network has a gateway and a fibre connection to EPCOR network in Churchill Station. The remainder of the TPSS in the system are connected on the second network which is via ISDN lines from the TPSS to EPCOR. The final network is a line of switches to interconnect the transfer trip signaling running between adjacent TPSS.

8.11.2 Transfer Trip

The transfer trip function isolates a fault and precludes the potential of a fault being fed from a secondary source. When a TPSS detects a Traction Power (TP) fault condition, it must send a signal to the adjacent TPSS to also trip its breakers. This network is made up of layer 2 switches that connect in a line with no redundancy. Refer to TP transfer trip in Chapter 6, Traction Power.

8.11.3 SCADA Control

The status of protective relays, transformers, negative disconnect switches, rail ground switches, 125 VDC auxiliary system, and circuit breakers in the TPSS is remotely monitored (for information only) by SCADA from the EPCOR Control Centre. This system is under the jurisdiction of EPCOR from Churchill substation out of EPCOR's control center. The Operator owns the equipment within the TPSS and the network that interfaces with EPCOR's system at Churchill Refer to Chapter 6, Traction Power.

8.11.4 Redundancy

The LRT System SCADA network currently has ring redundancy, but the transfer trip network does not. This functionality may be modified by future network designs that may use MPLS to converge these networks into a common architecture and network.

8.11.5 Traction Power Fibre Backbone

To reduce the likelihood of field disconnection of fibre, the Operator has dedicated buffer tube number 12 in the 144-fibre backbone for the exclusive use of TP. This buffer tube is currently spliced directly from the backbone into the TP room and the only location any changes may be made is in the TP room with EPCOR supervision.

8.11.6 Optical Isolation

The RTU in the TPSS are interconnected with fibre optic cables, for optical isolation from high power electrical equipment. CAT6 copper connections to switches must not be used and all connections from RTU to switches must be fibre optic to prevent any surges from damaging the network devices.

8.12 OTHER SUBSYSTEMS

Other subsystems requiring communications support include the following:

8.12.1 BMS System

The Building Management System (BMS) provides control and monitoring for building automation of HVAC systems and includes other monitoring points such as generators, power transfer switches, and switch blowers. Refer to Chapter 12, Mechanical for additional details on BMS requirements. The communications system must provide network infrastructure to interconnect BMS supervisory controllers and HMI server.

8.12.2 Smart Fare System

Power and network connectivity must be provided to Smart Fare Vending Machines (SFVM) and Smart Fare Validators (SFV) at Stations and on Platforms. Refer to Chapter 10, Station and Ancillary Facilities.

SFVM must have utility/generator power, network connection, and BMS sensors. SFV must have a data connection that provides power through POE.

Smart Fare equipment and software must conform to equipment and software currently in use on the LRT System.

8.12.3 Intrusion Detection and Card Access Control System
The LRT System currently uses the Tyco C-Cure security system with network connectivity that may be provided by the Operator through a fire-walled connection. The following security system devices must be provided:

- Magnetic door locks and status notification
- Door strikes and status notification
- Door position switches and contacts
- Door holders and status notification

The LRT OCC must be able to monitor and control access to exterior doors during unoccupied periods through occupancy scheduled alarming. Access to all interior doors for non-public spaces must be monitored and 24/7 alarming at doors not regularly accessed or at high security areas must be provided. Occupancy scheduled alarming at doors that are frequently accessed must be provided. Door status for interior doors to public spaces must be monitored and door hold open controls must be provided where required by the Operator.

Hardwired interconnections from the security system to the CCTV System for high security area door monitoring must be provided. Operational details are provided in Chapter 10, Stations and Ancillary Facilities. If a high-level rated security door is opened, hardwire interlocks must signal the CCTV system to display the specific camera for the door. Interconnection requirements must be coordinated with the CCTV system Designer. These interlocks must be via dry contacts from the C-Cure system.

For Intrusion Detection and Card Access Control System requirements, refer to "City of Edmonton Facility Design & Construction Consultant Manual, Volume 2, Technical Guidelines v4.0, Appendix C".

8.12.4 Public Wi-Fi
The Owner is committed to providing Patrons and the public with a free public WiFi service at all Stations and Transit Centre locations. The objective of the public WiFi network is to provide reliable "best effort" wireless communications for Patrons and the Operator's personnel in underground, surface, or elevated Platforms and Transit Centres.

Open City WiFi communications technologies for Stations, Platforms and the Operator's building locations must be coordinated with the City of Edmonton Open City & Technology (OCT) branch.

For information on Network Access Rooms (NARs) and WiFi, refer to City of Edmonton Facility Design & Construction Consultant Manual, Volume 2, Technical Guidelines v4.0, sections 2.5 and 2.6.

8.12.5 Third Party Advertising
The Owner contracts with third party advertisers who provide electronic signage on Platforms and in Transit Centres.

The Designer must consider conduit pathways, cabling infrastructure, power, and network capacity in Station communications systems design to support this advertising platform. The details of power and network connectivity must be part of commercial discussions between the third-party advertisers and the Owner.

8.12.6 Third Party Connectivity
The Owner and Operator may offer commercial opportunities for third-party enhancements and upgrades within the LRT public realm. Such enhancements and upgrades will be subject to the same performance requirements and standards as all other Owner systems. Communication system considerations will

include power, network connectivity, and possibly TELUS telephone lines depending on the application. Security system integration may be required. Commercial opportunities may include the following:

8.12.6.1 Automated Teller Machines

Public Automated Teller Machines (ATM) will require pathway conduits for both power and network connectivity to the Station communication room. Strategic and secure deployment locations within the Station footprint will require consultation with the third party. The details of power and network connectivity will be part of commercial discussions between the third party and the Owner.

8.12.6.2 Vending Machines

Public vending machines may require pathway conduits for both power and network connectivity back to the Station communication rooms depending on the sophistication of the vending machines. Strategic and secure deployment locations within the Station footprint will require consultation with the third party. The details of power and network connectivity will be part of commercial discussions between the third party and the Owner.

8.12.6.3 Coffee Shops and Portable Food Kiosks

Coffee shops and portable food kiosks may require communications in Station plaza spaces. The details of how these services may be furnished will be part of commercial discussions between the third party and the Owner.

8.13 TESTING AND COMMISSIONING

Refer to Chapter 1, General for details on Testing and Commissioning.

CHAPTER 9

Structures

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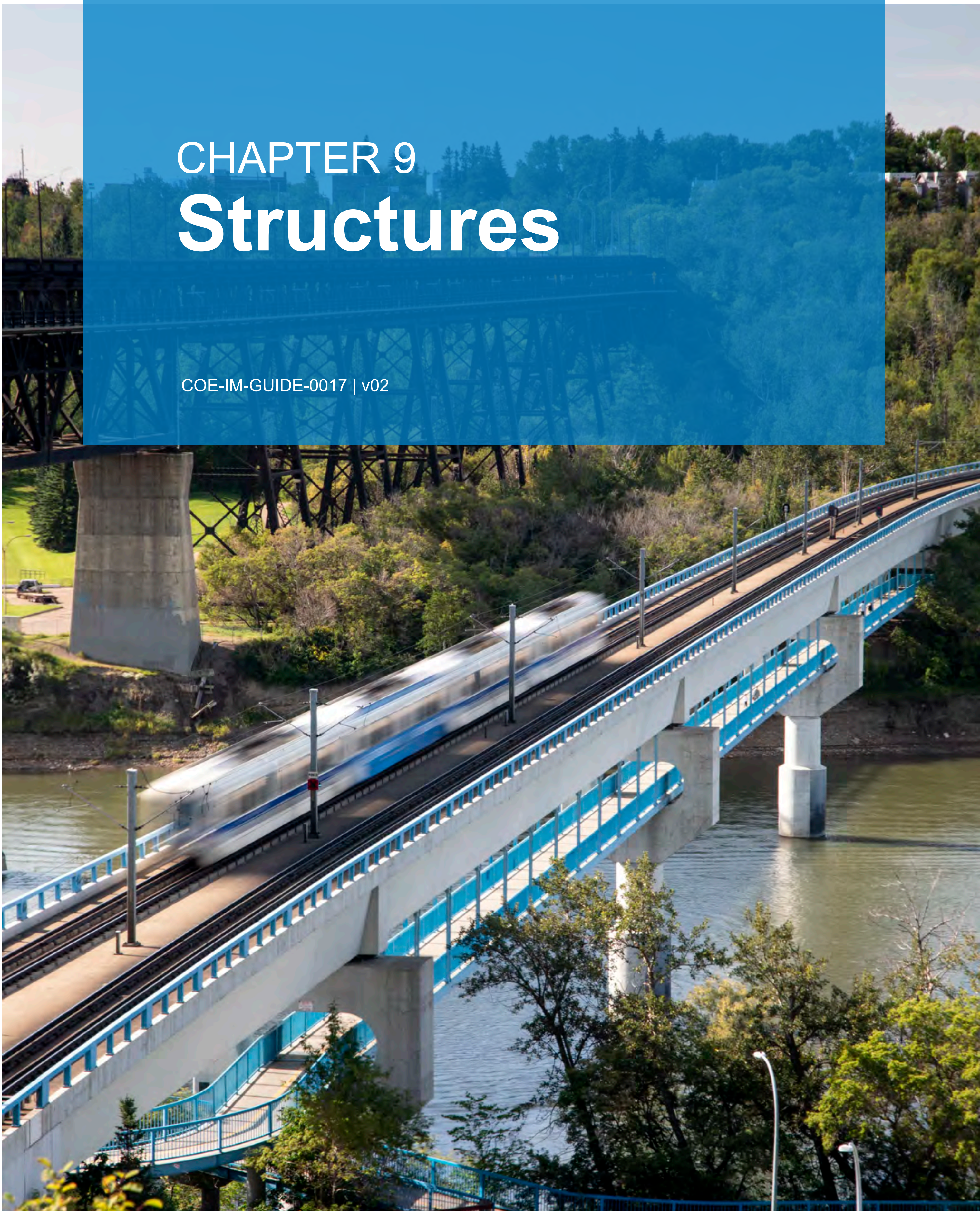

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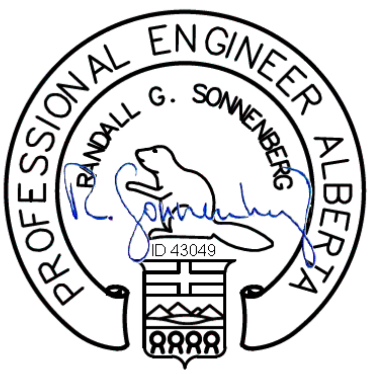

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9 STRUCTURES

9.1 INTRODUCTION

This chapter presents structural design guidelines, requirements, and standards for design of Light Rail Transit (LRT) structures. The various types of structures, their loading conditions, and their expected service life are discussed.

9.1.1 Applicable Codes, Standards, Practices, and Reference Guidelines

The most current edition of listed codes, standards and reference guidelines must be used.

9.1.1.1 Codes and Standards

- CSA S6 - Canadian Highway Design Code (CHBDC) [3]
- CSA S413 – Parking Structures [151]
- Alberta Building Code (ABC) [152]
- National Building Code of Canada and Commentaries (NBC) [2]
- City of Edmonton Design and Construction Standards Volume 1 and 2 [153] [15]
- Alberta Transportation - Bridge Structures Design Criteria (AT-BSDC) [154]
- Alberta Transportation - Standard Specifications for Bridge Construction [155]
- AASHTO LRFD Bridge Design Specifications (AASHTO LFRD BDS) [156]
- American Railway Engineering & Maintenance of Way Association (AREMA) [39]
- Eurocode 1: Actions on Structures – Part 2: Traffic loads on bridges (EN 1991-2) [157]

9.1.1.2 Technical References

- Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130) [17]
- Track Design Handbook for Light Rail Transit [158]
- Recommendations for Stay-Cable Design, Testing, and Installation [159]
- Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (AASHTO LFRDLTS) [160]
- Technical Manual for Design and Construction of Road Tunnels - Civil Elements [161]
- Guidelines for the Design of Footbridges [162]
- Footbridges - Assessment of Vibrational Behavior of Footbridges under Pedestrian Loading, Technical Guide, Sétra, Sétra /AFGC working group, Paris, France, October 2006 [163]
- Road traffic noise reducing devices [164]
- Manual of Design Criteria for Maintaining and Continued Operation of Facilities and Systems [165]
- AISC Design Guide 11: Vibrations of Steel-Framed Structural Systems Due to Human Activity (AISC 11) [166]

9.1.1.3 Practices and Reference Guidelines

The document listed below provides the Designer with guidelines and process for acceptance and installation of infrastructure in LRT tunnels.

- LRT Infrastructure in LRT Tunnels — Edmonton Transit System (ETS) Standard Operating Procedure [167]

9.1.2 Service Life and Design Life

Refer to Chapter 1, General for overarching design life requirements.

Service life and design life are two concepts that establish the parameters for the design of a structure. Service life is the period of time during which a structure element, component, subsystem, or system is expected to provide its desired function with a specified level of maintenance established at the design stage. Design life is the period of time specified by the Owner during which the structure is intended to remain in service.

Non-replaceable components must have service life to match at least the design life of the entire structure. Replaceable components must have service life consistent with the schedule of maintenance and replacement specified during the design stage.

Relevant design standards and calculations must be used to demonstrate, to satisfaction of the Engineer, that the service life requirements are met.

9.1.3 Inspection and Maintenance Requirements

All structures must be designed to accommodate inspection and maintenance activities. The following factors should be taken into consideration by the Designer:

- Access for inspection and maintenance
- Provision for the replacement of components with limited service life
- Track maintenance requirements
- Traction Power (TP) and Signal system requirements
- Corrosion protection measures
- Method of snow removal
- Control of stormwater run-off

The Design must include a draft inspection and maintenance section that identifies critical areas of the structure, the frequency of inspection, and guidelines for maintenance/repair procedures. It is understood that this draft content cannot be finalized until the structure is complete and the selection of components is known. The draft inspection and maintenance content from the detailed Design submission will be incorporated in the Operations and Maintenance (O&M) manual prepared by the Contractor for the structure. Refer to Chapter 1, General.

9.1.4 Structure Types

Structure types constructed for the LRT System fall into several categories. Table 9.1 contains a non-exhaustive list of the structure types, together with specified design standards and required design life.

Table 9.1 Structure Types

Structure Category	Structure Type	Primary Design Standard	Secondary Design Standard	Design Life (years)
Transportation Structures	Bridges	CHBDC		100
	Track Slab	CHBDC		75
	Earth Embankments and Cut Slopes	AT-BSDC		75
	Earth Retaining Structures	CHBDC		75
	Underground Structures	CHBDC		100
	Portals and Approaches	CHBDC		100
	Noise Attenuation Walls	CHBDC		75
Stations	Stations – Elevated	CHBDC	ABC	
	Stations – At-Grade	ABC		
	Stations – Underground	CHBDC	ABC	100
Surface Facilities And ROW Structures	Support Systems for ROW Devices	ABC		75
	LRT Operation and Maintenance Facilities ((OMF)	ABC		75
	Traction Power Substations (TPSS) and Utility Complexes (UC)	ABC		75
	Electrical Ductbanks and Vaults	ABC		75

CHBDC may be supplemented with design requirements from other codes and standards provided that reliability index criteria are compliant with Section 3.5.1 of CHBDC.

The remainder of this chapter focuses on design requirements supplementary to the primary design standards. Any ambiguity or conflicting directives are to be resolved to the satisfaction of the Engineer.

9.2 BRIDGES

9.2.1 Bridges Carrying LRT Tracks

A schematic cross-section of a bridge carrying LRT tracks is shown in Appendix 9A Figure 9.1. Major functional elements affecting the overall width of the bridge include the Trackway itself, Walkways and Refuge Zones, barriers, catenary supports, and possible inclusion of an active mode facility (pedestrian walk, Shared Use Path (SUP), or cycle track) on one or both sides of the bridge.

Chapter 3, Clearances and Right-of-Way, provides dimensions for the Trackway and Designated Egress Walkways and Refuge Zones are provided in Chapter 19, Definitions. Emergency egress design must follow the requirements of NFPA 130 [17].

Barriers must be designed for a derailment event (Section 9.9.6). Barriers must be located outside of the Walkway/Refuge Zone, on either the bridge parapet or between the active mode facilities and the LRT ROW.

Support for the Overhead Contact System (OCS) may be provided by catenary poles between two tracks or on either side of the Trackway. The portion of the Trackway used for catenary pole support cannot be used for emergency egress but may be used as a Refuge Zone.

The Designer must confirm the type of track structure on the bridge. Where tie and ballast track is used, the ballast shoulder must be retained by a curb or equivalent structure. The Designer must implement appropriate measures to prevent ponding of water on bridge decks. The drainage system design must satisfy requirements for stormwater design provided in Chapter 16, Utilities and Drainage.

9.3 CATENARY POLE SUPPORTS

Supports for the OCS poles/masts must be designed to limit damage to the supporting structure in the event of a Train or motor vehicle impact with the pole. The Designer must propose a design strategy to be reviewed and accepted by the Engineer. Typical strategies include designing the supporting structure to be reliably stronger than the pole itself or providing a base anchorage system designed to be weaker than the break away strength of the supporting structure. The pole supporting structure must have a design capacity at least 20% above the nominal capacity of the pole or base anchorage system. Refer to AASHTO LFRDLTS [160] for further design guidance.

Design and installation of proprietary OCS pole support systems, with breakaway anchorage, must be reviewed and accepted by the Engineer. Chapter 6, Traction Power, provides information regarding loading and functional requirements of the pole/mast support and its interface with the pole/mast.

9.4 EARTH RETAINING STRUCTURES

Walls adjacent to a Trackway for the purpose of retaining fill or cut slopes must be designed in accordance with site-specific geotechnical recommendations. Refer to Chapter 3, Clearances and Right-of-Way.

A drainage layer must be provided behind retaining walls to mitigate the build-up of hydrostatic pressure. Both water pressure and the lateral soil pressure must be considered in the design.

The design and installation of proprietary support systems, typically Mechanically Stabilized Earth (MSE) walls, must be reviewed and accepted by the Engineer.

The Designer must select face treatments for retaining walls that satisfy the requirements of Chapter 14, Urban Integration. The top of the wall must be fenced for public safety.

9.5 UNDERGROUND STRUCTURES

Typical structures may include, but are not limited to, mined tunnels, box tunnels, shafts and Cross-Connections. Refer to Chapter 3, Clearances and Right-of-Way for typical dimensions and required elements in a mined tunnel or a box tunnel.

Design criteria for these specialized facilities must be developed by the Designer and submitted as a separate design report, which must be accepted by the Engineer prior to proceeding with final design.

All tunnels must be designed to accommodate traction electrification, utilities, electrical and communication ducts and ductbanks, fire line pipes, and Designated Egress Walkways/Catwalks in accordance with the guidelines and figures in Chapter 3, Clearances and Right-of-Way and Chapter 15, Safety and Security. No fixed infrastructure may be located within the Vehicle Running Clearance Envelope (VRCE). The design of emergency egress from tunnels must follow NFPA 130 [17].

9.5.1 Mined Tunnels

Mined tunnels may be of two types, Sequential Excavation Method (SEM) and Tunnel Boring Machine (TBM), named for the technique used to construct them. Each construction technique affects the tunnel shape and details of the structural design but has no impact on functional requirements.

A SEM tunnel is built in two main stages. First, the tunnel is excavated in short incremental steps, with temporary support for the excavation provided by a high-performance shotcrete liner at each step. Second, a permanent liner, usually reinforced, cast-in-place concrete, is installed. The cross section of an SEM tunnel is approximately circular but flattened at the base.

A TBM tunnel is constructed by a continuous process. The leading face of the TBM bores the tunnel while the housing of the TBM supports the excavation. The trailing part of the TBM installs a liner, usually made with precast concrete segments. Because a TBM tunnel is bored, it has a circular cross section.

At the time of writing, there is no uniformly adopted standard in North America for the design of mined tunnels. Design of LRT tunnels in Edmonton must be based on sound engineering principles and local ground conditions. The Designer must develop a complete model of the interaction between soil, structure, and construction technique.

For further information, the Designer should refer to the Technical Manual for Design and Construction of Road Tunnels - Civil Elements [161] and Metro Rail Design Criteria [168] for the design of LRT tunnel linings.

9.5.1.1 Twin Tunnels

The spacing of twin tunnels must account for the effect of construction on the properties of the soil column separating the two tunnels. The distance between centrelines of two parallel tunnels must not be less than 2 times the outside diameter of the excavated face unless justified by a detailed investigation.

9.5.1.2 Instrumentation

The Designer must provide a plan for monitoring the response of the tunnel structure and the ground around the tunnel during construction to confirm that the soil-structure system is behaving as expected and to guide any corrective actions. The type and amount of instrumentation needed depends on local ground conditions and the level of risk associated with ground loss at the site.

9.5.2 Box Tunnels

Box tunnels include cut-and-cover, cover-and-cut, and jacked structures. Cut-and-cover tunnels are built in an excavation from the bottom up and then covered. Cover-and-cut structures are built from the top down, starting with foundation wall supports followed by a roof structure. The tunnel is then excavated below the roof. Jacked structures are usually segmental precast concrete, pushed horizontally through the ground with a combination of excavation at the tunnel face and hydraulic rams pushing at the rear.

The design of box tunnels should be compatible with a proposed construction method. The proposed method and sequence of construction should be submitted to the Engineer for acceptance before proceeding with detailed design.

The thickness of walls and slabs forming the outer shell of an underground box structure must provide the required strength and performance but in no case be less than 600 mm unless justified by analysis and approved by the Engineer.

Joints that allow movement (construction, expansion, contraction) must be identified and designed for water-tightness and structural integrity. Construction joints should be provided at locations of major changes in the structure section.

Where a tunnel section meets a Station, the connection must be designed either to accommodate differential movements or to transmit restraint forces.

Cast-in-place concrete slabs and walls must incorporate measures to accommodate movement resulting from temperature change and shrinkage. The spacing of control joints to limit shrinkage stresses and cracking must be provided as appropriate for the circumstances but in no case at a spacing greater than 15 m. For all exterior structural elements in contact with soil or rock, construction joints must have reinforcing steel continuous across the joint, and include shear keys, roughened surfaces or other means of shear transfer.

9.5.3 Shafts and Cross-Connections

Shafts inclined more than 45º from vertical must be designed as tunnels.

Emergency egress requirements for shafts and Cross-Connections include but are not limited to:

- Hatches and doors that open in the exit direction at the Trackway and ground surface levels
- Hatches and doors that allow easy exit by means of panic hardware and prevent unauthorized entry by means of a locking device
- Doors that meet the specified fire rating
- Continuous handrails on stairways

Shaft design must include measures to divert surface water into the drainage system away from hatches.

9.5.4 Water Ingress and Corrosion Protection

The Designer must develop a waterproofing and drainage system to address water ingress into underground structures. The waterproofing and drainage system will depend upon the type of buried structure. Where the type of structure limits the effectiveness of waterproofing, such as for a tangent pile wall, the system must provide year-round free drainage of seepage water.

Mined tunnels must include a durable structural liner and include a membrane or other waterproofing system. Design of the liner must be compatible with measures taken to prevent corrosion and eliminate Stray Current which are provided in Chapter 13, Corrosion and Stray Current.

Membrane waterproofing, or similar accepted systems, must be provided over the surface of cut and cover structures. Non-metallic water stops must be provided at construction joints. Measures such as the provision of channels to intercept water seepage may also be considered if total water tightness is problematic or cost prohibitive.

9.6 PORTALS AND APPROACHES

Portals are sections marking either the end of a tunnel or a location where the tunnel cross-section changes. An approach is a segment of structure, usually channel or U-shaped, designed to take the track from At-Grade to below grade.

Portals must be designed in a manner that limits the rate of change of air pressure on a Train as it passes through. Historically, guidance for the design of tunnel portals for the Edmonton LRT has been based on criteria that can be found in the WMATA Manual of Design Criteria [165]. The material that follows is based on this source. It is up to the Engineer and Designer to decide whether these criteria are appropriate for a design.

Pressure rise is a function of both the cross-sectional area of the portal entrance and the entrance speed of the Train. Rate of change pressure requirements are assumed to be met for a single track SEM tunnel with design speed less than 75 km/h, for a box section or single-track circular tunnel with design speed less than 65 km/h, for a portal at an underground Station, or if a tunnel is less than 60 m in length

For cases not meeting any of the above, the required cross-sectional area of the tunnel at the portal is a function of the design speed of the Train and the ratio of the cross-sectional area of the Train to the cross-sectional area of the tunnel, R (see Appendix 9A Figure 9.2).

In rare cases (high design speed or constrained tunnel cross section), a transitional section may be needed. A transitional section is a length over which the tunnel cross section is not constant. Design parameters for transition geometry are provided in the Manual of Design Criteria [165]. Two acceptable approaches for design of portal transition are outlined: a flared transition, in which the tunnel cross sectional area gradually reduces from a maximum at the portal to its typical size; and a tapered slot transition, in which a long V-shaped slot is provided in the tunnel roof.

9.7 STATIONS

Station types are provided in Chapter 10, Stations and Ancillary Facilities.

9.7.1 Underground

The anticipated construction technique for underground Stations must be submitted to the Engineer for review and acceptance. Design of underground Stations must meet requirements in Section 9.5. The Designer must meet the requirements of ABC [152] for use and occupancy.

9.7.2 At-Grade and Elevated

Platform height and edge clearance dimensions are provided in Chapter 3, Clearances and Right-of-Way.

The Designer must consider resonance between the structure and pedestrian traffic. The natural frequency of an unloaded structure must not be less than 2 Hz. The calculated live load deflection must be limited to 25 mm.

The structure's supporting elevators and escalators must be designed for maximum dead and live load capacity provided by their manufacturer.

Control joints must be provided at a spacing of no more than 15 m to limit shrinkage stresses and cracking.

Elevated Stations support a combination of occupancies that is not addressed by a single design code. Those portions of the structure not supporting rail traffic must be compliant with ABC [152]. For elements within the structure that support a combination of rail traffic and other occupancies, the Designer should propose case-specific design criteria for approval by the Engineer.

For any elevated structure, the Designer must assess the risk associated derailment of LRVs. The use and occupancy of the area below the elevated structure that would be impacted by a derailment must be included in that assessment. The designer must submit, for the Engineer's review and acceptance, a recommendation for barriers that are appropriate for the particular circumstances of the elevated structure being considered. Where the assessed risk is high, the Designer should consider meeting the strength requirements of a bridge barrier (see 9.9.6 Derailment Forces).

9.8 TRACTION POWER SUBSTATION AND UTILITY COMPLEXES

TPSS design must be in accordance with ABC [152] to support mechanical and electrical systems and use and occupancy provided in Chapter 6, Traction Power.

The Designer must determine if the use of a clean agent fire suppression system will result in structural components within a Utility Complex being subject to implosion/blast loading.

9.9 DESIGN LOADS

The Designer must establish design loads in accordance with the appropriate design codes and standards (see Table 9.1). This section presents additional requirements to be considered in the Design.

9.9.1 Dead Loads

Dead loads must include, but are not limited to the weight of the following items:

- Ballast
- Track ties
- Track slab
- Plinths, rail fastening components, and rails
- OCS
- Traction Power System (TPS) cabling, wiring, and related hardware including support poles
- Signal systems cabling, wiring, and related hardware including Signals and support masts
- Partitions
- Service walkways
- Lighting fixtures and their supports

9.9.2 Live Loads – Non-Transportation Structures

Publicly accessible areas of Stations and Platforms must be designed for a minimum live load of 4.8 kPa.

Live load due to LRT specific components must be considered. These components include but are not limited to:

- Platform furniture
- Machinery
- Electrical equipment
- Pumps
- Battery and generator systems
- Escalators
- Materials needed to service and clean Stations
- TPSS-specific equipment including transformers and wall-mounted switches

9.9.3 Live Load – Design Vehicles

Design vehicles for LRT structures may include on-track vehicles (either a work Train or a design Train), and highway vehicles. The design vehicles and trains described here and shown in Figures 9.3 and 9.4 are specified by the City of Edmonton and the Engineer for use by the Designer. The design vehicles shown in Figures 9.3 and 9.4 are what have been used in past designs of the existing LRT System.

The design weight and wheel configuration of a single Light Rail Vehicle (LRV) is shown in Appendix 9A Figure 9.3. The design Train consists of five such LRVs at a design speed (distinct from operating speed) of 80 km/h.

The configuration of vertical static wheel loads of a work Train is shown in Appendix 9A Figure 9.4. The work Train loading is applied as a single vehicle (locomotive, three dump cars, one spot ballast car) at a design speed of 40 km/h on any one track.

Designing for a work Train may result in substantial additional cost, especially on long-span structures. In these cases, the Designer should alert the Engineer to the circumstances and confirm design loading requirements.

If other vehicular traffic is expected to be operated on an LRT structure, highway loads must also be considered as per CHBDC [3], with CL-800 as a design CL-W load. If required, overload vehicle configurations must be provided by the Engineer and accounted for in the Design.

9.9.4 Live Load – On-Track Vehicle – Vertical Load

9.9.4.1 Dynamic Load Allowance (DLA)

For local effects due to loading from one bogie, the DLA is 1.00. At minimum, the DLA for global effects is based on EN 1991-2 with standard track maintenance assumed. The Designer must consider whether a larger DLA is justified.

$DLA = \Phi - 1$, with $0 \leq \text{DLA} \leq 1$,

Where, Φ is the dynamic factor according to EN 1991-2 [157].

Note: DLA does not apply to Train horizontal live loads.

9.9.4.2 Rolling/Lurching Load

Rolling or lurching load occurs due to lateral shifting of the on-track Train vertical live load from one rail to another. The design rolling/lurching demand applied to the structure must be the governing of:

- 45% of the Train vertical live load on one wheel of an axle and 55% on the other wheel of the axle
- The maximum load imbalance allowed by the Train suspension

9.9.4.3 Multi-Track Loading

For bridge decks supporting multiple tracks, the Train load must be applied as follows:

- 2 tracks - 100% on each track
- 3 or more tracks - 100% on any 2 tracks and 75% on any additional tracks

The Designer must apply one work Train or one design Train per track for strength and serviceability considerations for all structural elements. Only one work Train is required to be included in any load combination.

9.9.4.4 Distribution of Wheel Demands

Distribution of Wheel Demands to Slab for Tie and Ballast Track

For tie and ballast track, wheel loads are transmitted to the deck slab through the ballast. The Designer may assume that wheel loads are uniformly distributed longitudinally over a length of 900 mm, plus the depth of the track structure, plus twice the effective depth of slab, except as limited by wheel spacing. Wheel loads may be assumed to have uniform lateral distribution over a width equal to the length of the tie plus the depth of ballast under the tie, except as limited by the proximity of adjacent tracks or the extent of the structure.

Distribution of Wheel Demands to Slab for Direct Fixation Track

For direct fixation track, wheel loads are transmitted to the deck slab through the rail fastening system placed directly on the slab. The Designer may assume that the wheel loads are uniformly distributed over a length of 900 mm along the rail. This load may be assumed to be distributed transversely (normal to the rail and centred on the rail) by the width of rail fastener pad plus twice the depth of deck and track support structure except as limited by the proximity of adjacent tracks or the extent of the structure.

9.9.5 Live Load – Train Horizontal Demands

The Designer must consider horizontal forces from Train acceleration, braking, centrifugal forces and nosing (hunting).

9.9.5.1 Train Longitudinal Demands

Acceleration Forces

To determine LRV acceleration demand, a force equal to 15% of the design Train load without impact should be applied at the centre of gravity of the Train above the Top of Rail (TOR). Refer to AREMA [39]. Consideration should be given to combinations of acceleration and braking forces where the structure includes more than one track.

For tie and ballast track with Continuous Welded Rails (CWR) spanning the entire bridge structure, the Designer may assume that up to 50% of longitudinal force due to acceleration, braking and rail restraint is transferred to the CWR anchor point outside the bridge structure. Refer to AREMA [39].

Vehicle Braking Forces

A longitudinal braking and traction force equal to 25% of the static vertical live load must be applied on all loaded tracks at the top of the uppermost rail.

9.9.5.2 Train Transverse Demands

Centrifugal Forces

Structures carrying non-tangent track must be designed for centrifugal loads according to CHBDC [3] with “v” being at least the maximum design speed of the Train.

Nosing/Hunting Forces

A minimum hunting or nosing load of 50 kN must be applied at the TOR over the length of one bogie, but not over a length of more than 1.5 m, at the location on the structure resulting in the most unfavorable load effect. Hunting or nosing forces are applied simultaneously with centrifugal forces.

9.9.6 Derailment Forces

Train derailment load, including both vertical and horizontal loads, must be treated as a collision load, "H", in CHBDC [3].

In the absence of actual crash test data or results of a detailed dynamic crash/impact analysis, the load effect of a derailment event may be accounted for by applying concurrent vertical and horizontal forces to the supporting structure as follows:

- The Train must be positioned a perpendicular distance away from the track alignment to cause the maximum load effect, and be either:
  - Equal to the weight of three LRVs positioned parallel to the track axis with an impact factor (similar to, but in lieu of a DLA) equal to 100%
  - Equal to the weight of the work Train positioned parallel to the track axis with an impact factor equal to 50%
- Horizontal (transverse) load effect, equal to 10% of the Train weight, distributed in proportion to axle load along the length of the Train, acting perpendicularly (transverse) to the track alignment at an elevation 1.05 m above the top surface of the rail

Only one derailment event need be considered at a time. Concurrent with the derailment event, the non-incident track must be loaded with a stationary (DLA=0) Train.

Other methods of establishing a derailment design load presented by the Designer may be considered by the Engineer.

A derailment event is expected to apply an impact force to barriers. For a maximum vehicle operating speed of 96 km/h, the force, acting 600 mm above TOR and normal to the barrier, is 40% of the weight of a single LRV and is applied over distance of 3 m along the barrier. Guard rails or barriers protecting the track must be designed to resist this force. Refer to Track Design Handbook [158].

For derailment events that would cause the on-track vehicle to bear directly on a deck slab, the Designer must propose, for approval by the Engineer, a rational method for establishing the wheel load distribution on the slab.

9.9.7 Vehicle Collision Forces

Piers or other structure support elements that are less than 10 m from the edge of a Street must be designed for vehicle collision forces as per CHBDC [3].

9.9.8 Rail-Structure Interaction Demands

Loads created by rail-structure interaction must be considered and used as thermal loads, "K", in CHBDC [3].

Horizontal design forces resulting from interaction between rail and structure must be considered. The nature and magnitude of this interaction depends upon the track type.

In the case of tie and ballast track, the relative movement between superstructure and combined ties and rails is accommodated by slight movements of the cross ties within the ballast. As a result, tie and ballast track produces minimal thermal interaction forces between rail and structure.

Direct fixation involves attaching the rail to the supporting structure at discrete locations. Each direct fixation fastener is structurally connected to the supporting deck and holds the rail in place by means of a spring-loaded rail clip. The interaction force between rail and structure is limited by a frictional restraint at each clip. The value of the frictional restraint force should be provided by the manufacturer of the fastener. It is typically about 13 kN per clip but this must be confirmed by the Designer.

Embedded track is cast within the supporting slab. As a result, the support and restraint provided by the slab is continuous.

Wherever CWR is terminated, movement of the rail end must be restricted. The restraint will introduce a significant longitudinal force. CWR must not be terminated on aerial structures unless the structure is designed to withstand the additional imposed load.

Provision must be made for transverse (radial) and longitudinal rail/structure interaction forces resulting from temperature changes in the CWR. Refer to Chapter 5, Trackwork for properties of track. The magnitude of transverse and longitudinal rail forces must be determined by an analysis of the total structural system including rail fasteners, bearings and substructure. The method used to analyze rail/structure interaction forces is at the discretion of the Designer. Refer to the TCRP 155 [158] for further details on interactive force analysis.

The Designer must account for load effects resulting from broken rail. The Designer need only consider one broken rail on a given LRT structure, with forces based on a rail break gap no greater than 50 mm.

9.9.9 Environmental Demands

9.9.9.1 Snow Load

Snow load is not usually considered in the design of the Trackway or Streets because full snow load is not compatible with their function. Structures designed to store snow from clearing operations must be designed for the volume of snow that they are required to store. Design load for stored snow must be based on a maximum volume of snow with a density not less than 5 kN/m^3. Snow load must be treated as a live load “L” in CHBDC [3] with a load factor of 1.3 in all Ultimate Limit States (ULS) load combinations and with a load factor of 1.0 in Serviceability Limit States (SLS) 1 load combination.

9.9.9.2 Wind Load – Station Canopies

A wind study may be required to confirm loads on Station Canopy structures, where the form of the Canopy is not explicitly covered within the ABC [152].

9.9.10 Structure Specific Requirements

9.9.10.1 Earth Retaining Structures

For retaining structures constructed immediately adjacent to a Trackway, the Designer must determine if the structure is within the soil pressure influence zone from Train loading. If it is, surcharge loading of 20 kPa should be used for design of the retaining structure. Any adjacent surface elements, such as OCS supports, that may exert a surcharge load on the retaining structure must also be considered.

Soil loads applied to the earth retaining structure must be provided through a geotechnical report. Both water pressure and the lateral soil pressure must be considered in the design.

9.9.10.2 Underground Structures

The Designer must estimate the total vertical pressure that will be exerted on an underground structure. Earth load is estimated to be the total weight of soil using a soil mass density to be confirmed by a geotechnical engineer but not less than 2000 kg/m^3.

Horizontal earth pressure exerted on underground structures must be based on site-specific geotechnical recommendations.

Additional loading conditions for underground structures include, but are not limited to, the following:

- Live load of vehicles above or inside the structure
- Self-weight of the structure and infrastructure components
- Adjacent surcharge loads
- Hydrostatic pressure
- Effects of tunnel breakouts at Cross-Connections, portals, and shafts;
- Erection loads including external grouting loads
- Loads due to possible imperfect liner erection
- Loads resulting from construction of adjacent structures
- Seismic loads, where applicable
- Potential settlement or uplift of soil adjacent to structure

Permanent loads should be applied in stages to model the anticipated construction method and service life of the designed structure. For example, unbalanced backfilling of a cut-and-cover structure during construction must be considered in the Design.

Cut and cover structures must be designed for the larger of actual cover depth or a cover depth of 2.5 m. If a structure supports a roadway then the Design must be based on the actual depth of cover to be provided.

The Engineer may receive requests from crane operators to position their equipment over existing LRT tunnels, underground Stations or related underground facilities for the purpose of lifting materials or heavy equipment adjacent an underground LRT ROW. To assist the Engineer in accommodating these requests, the Designer must include information in the Design indicating the location and magnitude of permissible point loads.

9.10 LIMIT STATES DESIGN

9.10.1 Ultimate Limit State

In addition to ULS load combinations presented in CHBDC [3], LRT structures must be designed for:

$\alpha_D \times D + \alpha_E \times E + \alpha_P \times P + 1.0 \times L + 1.25 \times K + 1.5 \times (W+V)$ ULS Combination 4a

Where, α_D, α_E and α_P = load factors associated with permanent loads, as defined in CHBDC [1],
D, E, P, L, K, W, and V = loads and load effects as defined in CHBDC [1].

Design of LRT structures supported by stay cables or hangers must account for Cable Exchange Forces and Cable Loss Forces (CEF and CLDF), where CLDF is a dynamic force due to the sudden loss of one stay cable as defined by PTI [159].

In the case of CEF, only one LRT track needs to be in service. The Designer must choose a combination of cable to be exchanged, and track in service then present this choice in the draft Inspection and Maintenance Manual. For the cable loss load case, both tracks must be assumed in service.

$\alpha_D \times D + \alpha_D \times E + \alpha_D \times P + 1.5 \times L + CEF$ ULS Combination 10

$\alpha_D \times D + \alpha_D \times E + \alpha_D \times P + 0.75 \times L + 1.1 \times CLDF$ ULS Combination 11

LRT Structures erected using segmental construction must account for load combinations in accordance with AASHTO [160].

9.10.2 Serviceability Limit State

9.10.2.1 Deflection Criteria

Short and medium span bridges must meet deflection limitations of CHBDC [3] but in no case may the static deflection under live load plus DLA exceed 1/800 of a span and 1/300 of a cantilever. Long span bridge spans must satisfy the performance design criteria 1 through 7 of this section.

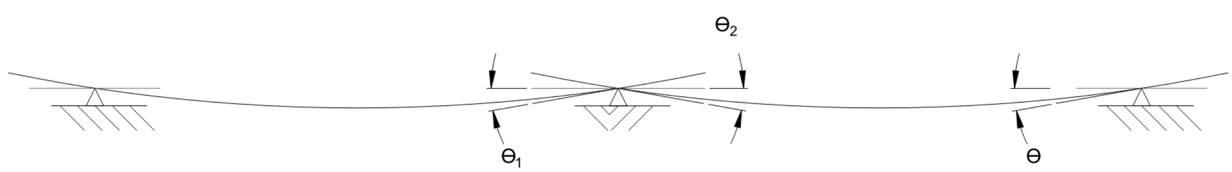
Performance criteria provided herein are based on international practice for long span railway bridges as reflected in Eurocodes EN 1990 [169] and EN 1991-2 [157], German Institute of Standardization (DIN) Fachbericht 101 [170], and UIC (International Union of Railways) Technical and Research Reports: D160/RP6 [171]. These criteria are intended to represent minimum requirements for operation of Trains and function of special trackwork, most notably rail expansion joints. The Designer must develop criteria specific to the requirements and circumstances of the project such as the ability of Trains to accommodate longitudinal and transverse slopes, or the ability of expansion joints to accommodate angular rotation.

Criterion 1: Maximum Vertical Deflection and Gradients of the Main Span

The maximum longitudinal gradient for the bridge must be limited to 6.0% for the SLS 1 load combination at the Train location.

Criterion 2: Maximum Angular Rotation – Vertical Plane

The maximum relative rotation in the vertical plane at joints between adjacent spans must be limited to $\theta 1 + \theta 2 < 5$ mrad, where θ is the vertical rotation as shown in the sketch below. Only unfactored live load including DLA on one track, creep, shrinkage, and temperature effects need be included.



Angle change between spans greater than the prescribed limit may be accommodated with appropriate detailing of rail expansion joints so that the angle change is spread over sufficient length to provide Passenger comfort. Refer to DIN-Fachbericht 101 [170].

Criterion 3: Maximum Angular Rotation – Horizontal Plane

The maximum relative rotation in horizontal plane at joints between adjacent spans must be limited to $\theta 1 + \theta 2 < 3.5$ mrad, where θ is the horizontal rotation in load combination SLS 1. Refer to Eurocode EN 1990/A1 Section A2.4.4.2.4 – Table A2.8 [169] for railway speeds $V \leq 120$ km/h.

Criterion 4: Maximum Transverse Slope of LRT Track

The maximum transverse slope of LRT tracks must be limited to θT < +/- 20 mrad for SLS 1 containing LRVs, and θT < +/- 30 mrad for SLS 1 containing the work Train, where θT is the torsional rotation of the deck. The maximum SLS 1 rotation must include a minimum 3 mrad allowance for tolerance in the dead load geometry. Criterion 4 is based on performance requirements specified by TCRP Report 71 (Vol 6) [172] and TCRP Report 57 [173] for LRT track surface geometry for the case where the tracks are designated Class 4 for LRVs and Class 3 for the work Train.

Criterion 5: Maximum Torsional Deformation per Unit Length – Deck Twist

The maximum deck twist must be limited to κ < 1 mrad/m for SLS 1 at the location of any LRV, and κ < 1.5 mrad/m for SLS 1 at a work Train location, where κ is the torsional deformation per length (warping). For SLS 1 containing LRVs, Criterion 5 is based on Eurocode EN 1990/A1, Annex A2.4.4.2.2 (2) [169]) for railway bridges with design speeds ≤ 120 km/h. The criterion is relaxed for the work Train as the work Train has a significantly slower design speed of 40 km/h. The specified requirements applicable to the LRVs and the work Train are more stringent than the requirements specified by TCRP [172], [173] for LRT track surface geometry.

Criterion 6: Runability – Derailment/Wheel Climbing

The ratio of the lateral to the vertical forces of a wheel must be limited to Y/Q < 0.8, for SLS 1 using the operating Train speed. Y and Q represent the dynamic lateral and vertical wheel force on the rail, respectively [174].

Criterion 7: Runability – Overturning Risk

Wheel unloading coefficient ΔP/P must be limited to ΔP/P < 0.9 for SLS 1 using the operating Train speed. Factors ΔP and P represent the wheel unload force and the static force, respectively. This criterion is based on European Standard EN 14067-6, subsections 5.4.3.4 and 5.4.4.1 [175].

9.10.2.2 Vibration Criteria

The structural system must be checked for resonance. If superstructure natural frequencies are within a range susceptible to resonance, either the structure must be adjusted or the vibration response mitigated by use of tuned mass dampers or alternative methods.

Design of LRT Structures must meet the requirements of CHBDC [3] for static deflection due to live loading for bridges designated “with sidewalks – occasional pedestrian use".

For LRT structures with a fundamental vertical flexural frequency of less than 3.5 Hz, the Designer must submit a Vibration Analysis Report, accounting for the interaction between the Train, pedestrian occupancy and the structure. That report must provide a summary of the methodology used to determine structure accelerations, and identify maximum accelerations to be experienced by both Passengers and pedestrians. Consideration must be given to both lateral and torsional vibration modes of the structure. Pedestrian occupancy is modelled using forcing functions specified by the FIB [162] and Technical Guide Footbridge.

Vertical acceleration in publicly accessible areas of Stations and Platforms must not exceed limits specified in AISC 11 [166]. These areas are designated as “indoor footbridges” for the purpose of evaluation according to AISC 11.

9.10.3 Fatigue Limit State

The fatigue limit state must be checked on structural elements. Special care is needed in areas with indirect or complicated load paths. The number of load cycles during the design life of a structure must be calculated using the projected LRT schedule, unless otherwise specified in the Contract Documents.

Provisions of CHBDC [3] for calculation of fatigue damage can be used with following amendments:

- $\lambda_1 \cdot f_{sr} < F_{sr}$
-
    - Where, λ_1 = a factor that accounts for the fact that the fatigue damage from a given number of cycles of actual traffic will be less than the fatigue damage from the same number of cycles of the Design Vehicle. If a loading histogram is not known, fatigue loading must be based upon fully loaded vehicles with λ_1 equal to 1.0.

Fatigue resistance F_{sr} is calculated using the estimated number of fatigue cycles. The fatigue stress range f_{sr} is calculated for the passage of a single Design vehicle including the DLA. For elements with a large influence surface, the critical loading event may be concurrent loading on both tracks.

Other methods of establishing a fatigue stress range f_{sr} and a calibration factor λ_1 presented by the Designer may be considered by the Engineer.

9.10.4 Structure-Specific Requirements

9.10.4.1 Earth Retaining Structures

The load factor for lateral earth pressure must be 1.5 for proportioning of earth retaining wall sections [153].

9.10.4.2 Underground Structures

The Designer must consider combinations of vertical and horizontal loads during design of underground structures. The structure must be designed so that net downward load at all stages of construction and operation is 10% greater than the calculated uplift from buoyancy. The following additional loading combinations must be considered:

- Full vertical loading with full horizontal loading on one side and one-half horizontal loading on the other side
- Full vertical loading with half horizontal loading on both sides

9.11 CONSTRUCTION REQUIREMENTS

LRT structures must be constructed in accordance with the City of Edmonton Design and Construction Standards (D&CS) [153] supplemented by sections of the Alberta Transportation Standard Specifications for Bridge Construction [155]. In the event of conflict, the more stringent provision applies.

9.11.1 Special Requirements for Mined Tunnels

In addition to construction tolerances referenced above, mined tunnels must satisfy the following:

- The inside face of a permanent liner must be within ±50 mm of the design alignment
- The tunnel must be constructed so that its centre-line is within ±50 mm of the longitudinal reference line
- The as-built finished inside face of the tunnel wall must be no more than 25 mm inside the as-designed finished surface of the tunnel

APPENDIX 9A – FIGURES

CITY OF EDMONTON
LRT DESIGN GUIDELINES

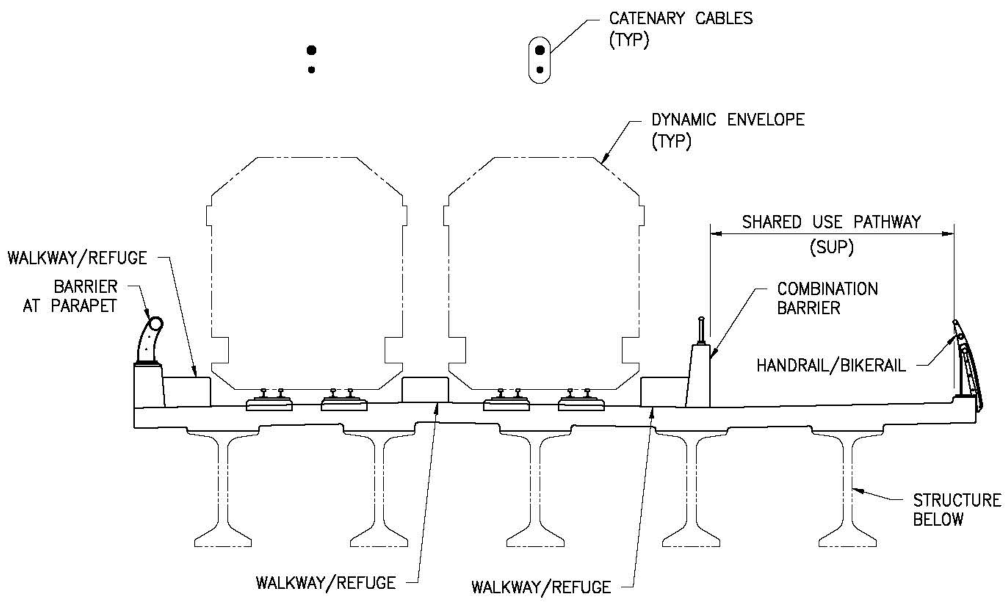
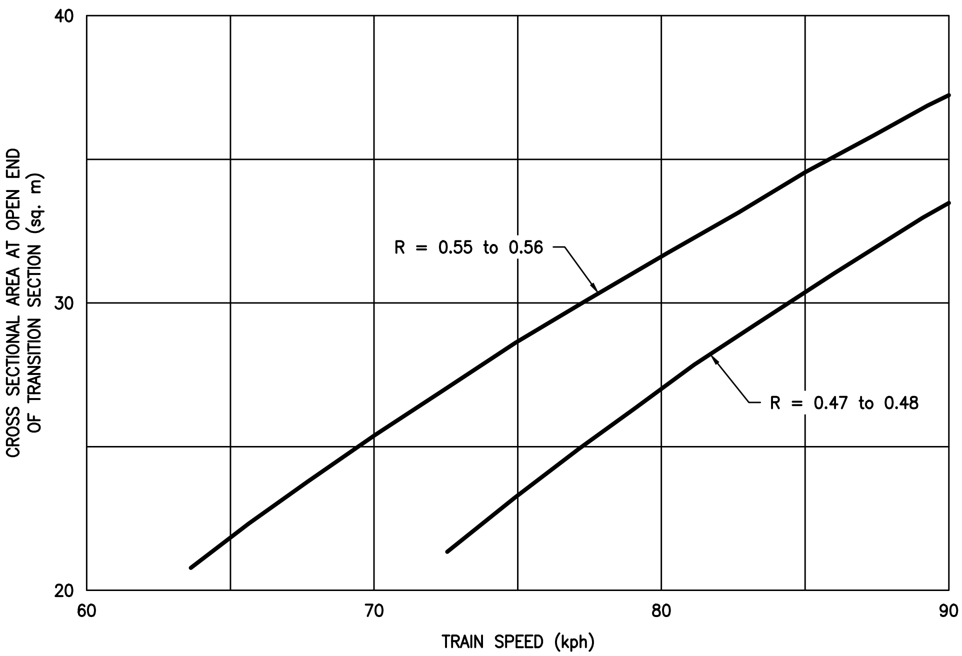


		FIGURE 9.1	CHAPTER 9
		SCHEMATIC	STRUCTURES
		BRIDGE SECTION	
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES



NOTE: Adapted from Department of Transit Infrastructure and Engineering Services, "Manual Of Design Criteria for Maintaining And Continued Operation Of Facilities And Systems," Washington Metropolitan Area Transit Authority WMATA, Washington DC, 2014

		FIGURE 9.2 RECOMMENDED AREA OF TUNNEL SECTION AT PORTAL	CHAPTER 9
			STRUCTURES
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

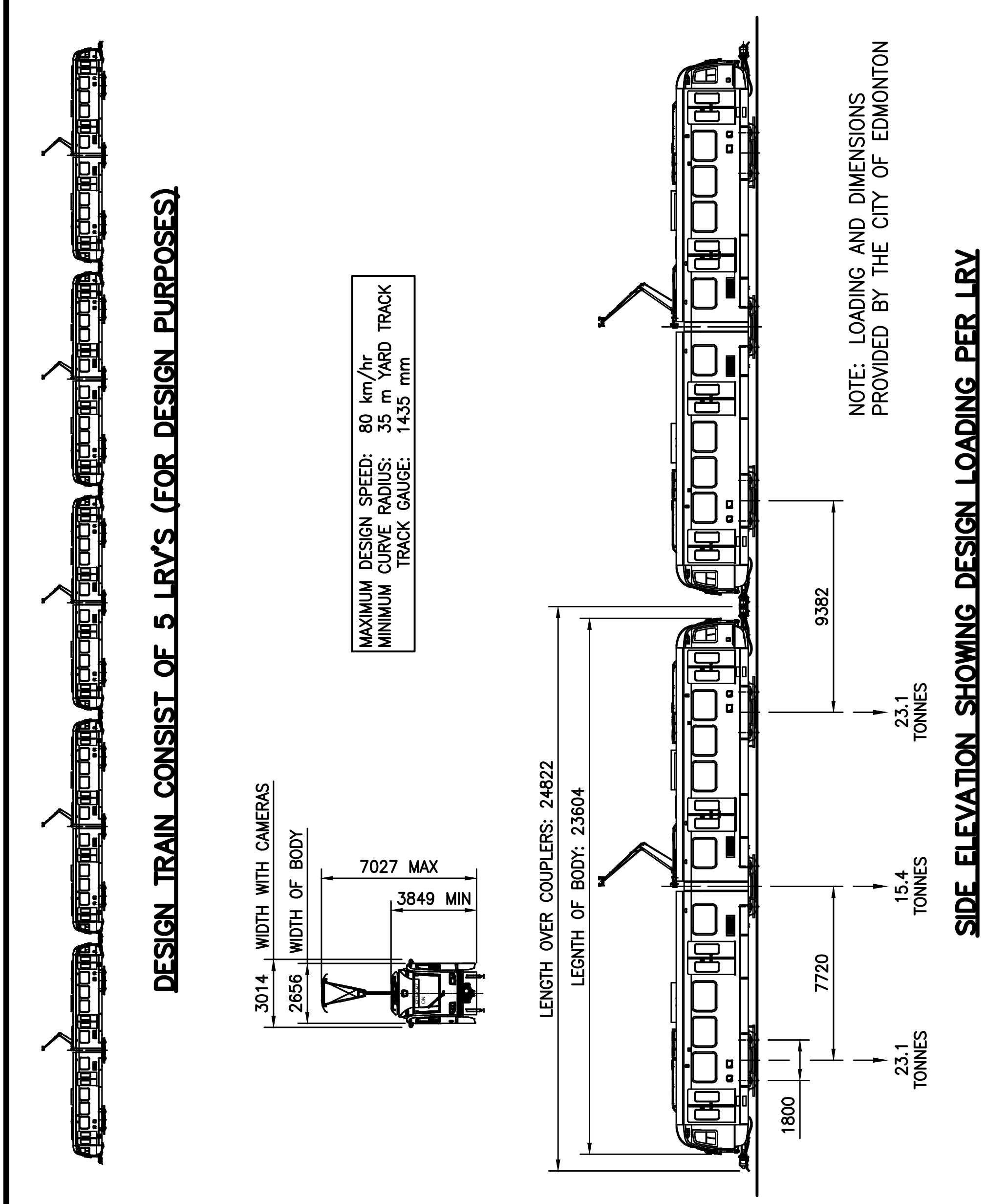


		FIGURE 9.3 DESIGN VEHICLE GENERAL CHARACTERISTICS	CHAPTER 9 STRUCTURES
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

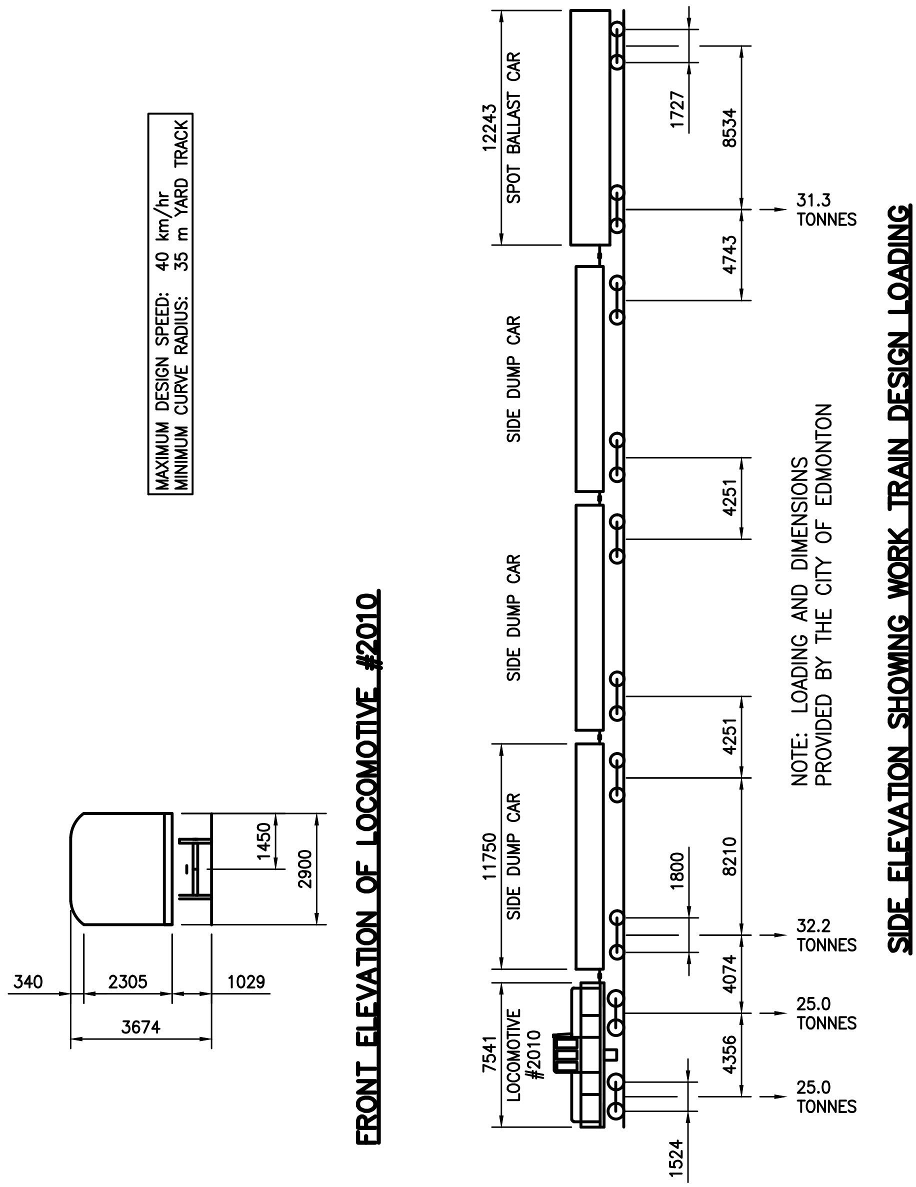


		FIGURE 9.4	CHAPTER 9
		WORK TRAIN	STRUCTURES
		GENERAL CHARACTERISTICS	
Date	Revision		

CHAPTER 10

Stations and Ancillary Facilities

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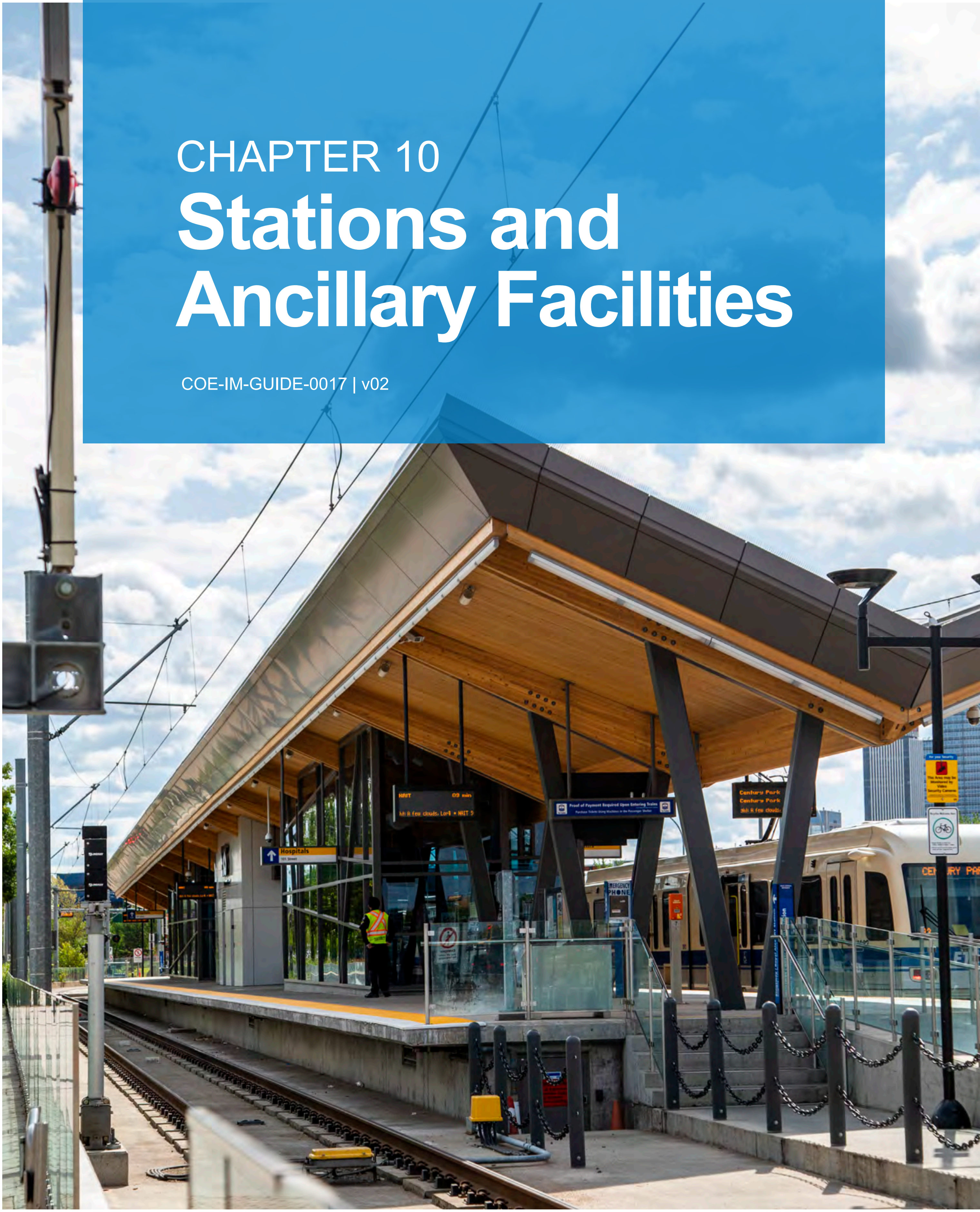

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INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

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10 STATIONS AND ANCILLIARY FACILITIES

10.1 INTRODUCTION

This chapter provides the guidelines and criteria for the design of Stations, associated Patron amenity areas and other related facilities for the Light Rail Transit (LRT) System. Ancillary buildings or structures required to support LRT operations include Patron overpass or underpass structures (pedways), Platform shelters, Utility Complexes, Traction Power Substation (TPSS) buildings, Signal equipment enclosures, and parking areas. Information is provided for both the fundamental design principles and the specific requirements for preparation of concept plans, preliminary designs, and detailed designs for new or renovated facilities. See Chapter 1, General for more information on the stages of design. Infrastructure requirements for multi-modal connections are described in Chapter 14, Urban Integration.

Designers should be familiar with the LRT System and the various Station types that exist in the current system. Where appropriate, new Stations should consider the Owner’s desire for an Urban Style LRT System and respect the principles of Sustainable Urban Integration (SUI). The design of Urban Style Stations must consider the neighbourhoods that surround them in terms of amenity, scale, connectivity, and Accessibility.

While there may be certain site-specific functional design elements that differ from Station to Station, standardized components must be provided to maintain consistency with ETS branding and identity. This will promote consistency in the design of Stations and Ancillary Facilities throughout the LRT System while providing operational efficiency and ease of maintenance for the Operator. Prescribed standardized components are defined in the Operator’s Preferred Products List, which will be provided to the Designer.

Proper coordination between all design disciplines must occur to permit incorporation and integration of the Station and Right-of-Way (ROW) systems, assemblies, components and materials. While this chapter primarily presents the architectural criteria for Stations and Ancillary Facilities, references to Station structural, electrical, mechanical and communication components are provided to assist in design coordination.

10.1.1 Applicable Codes, Standards and Regulations

While Stations fall under the definition of buildings in the National Building Code - Alberta Edition (NBC-AE), some of their operational characteristics do not align with normal building functions. Stations and Ancillary Facilities must be designed to meet the minimum requirements of all applicable Federal, Provincial, and Municipal codes, regulations, policies and bylaws. The Designer may request a variance from these, or other codes and standards may be applicable. These situations must be reviewed with the Engineer and the City of Edmonton Urban Form and Corporate Strategic Development Department as the Authority Having Jurisdiction (AHJ). All requested variances, whether code or guideline related, must be developed in consultation with the Engineer and the Operator.

Refer to Chapter 1, General for variance or design exception procedures.

10.1.1.1 Codes and Regulations Pursuant to the Alberta Safety Codes Act

- National Building Code of Canada, Alberta Edition, NBC, (NBC) [2]
- National Fire Code (NFC) [176]
- National Energy Code for Buildings (NECB) [177]
- Elevating Devices Codes Regulation [178]

10.1.1.2 Policies and Bylaws

- City of Edmonton Zoning Bylaw 12800 [179]
- City of Edmonton Bylaw 14054: Edmonton Design Committee Bylaw [5]
- City Policy C602 Accessibility for People with Disabilities (supersedes C463, C466 and the ETS Accessible Transit Instruction) [54]
- City Policy C532 Sustainable Building [10]
- City Policy C588 Winter City Design Policy [180]
- City Policy C458C Percent for Art to Provide and Encourage Art in Public Areas [9]
- City Policy C573A Complete Streets [181]
- City Policy C565 Transit Oriented Development [182]
- City Policy C554A Park and Ride [183]

10.1.1.3 Reference Standards

- NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems [17]
- NFPA 14 - Standard for the Installation of Standpipe, Private Hydrants, and Hose Systems [184]
- NFPA 72 (2019) Annex D "Speech Intelligibility" [185]
- CSA B44/ASME A17 Safety Code for Elevators and Escalators [186]
- APTA Heavy Duty Transit Escalator Design Guidelines [187]
- CSA S478 Durability in Buildings [188]
- CSA S413 Parking Structures [189]
- ANSI/IES RP-8-18 American National Standards Practice for Design & Maintenance of Roadway and Parking Facility Lighting [190]
- IES RP-33-14 Lighting for Exterior Environments [191]
- ANSI/NFSI 101.3Test Method for Measuring Wet DCOF of Common Hard-Surface Floor Materials [192]
- CSA B651-18 Accessible Design for The Built Environment [193]

10.1.1.4 Guidelines

- Alberta Barrier-Free Design Guide [194]
- City of Edmonton Access Design Guide [195]
- City of Edmonton Complete Streets Design and Construction Standards (CSDCS) [15]
- City of Edmonton Transit Oriented Development Guidelines [23]
- City of Edmonton Winter Design Guidelines [25]
- City of Edmonton Park and Ride Guidelines [196]
- City of Edmonton High Floor, Urban Style LRT Sustainable Urban Integration Guidelines
- Facility Design and Construction Consultant Manual, Volume 1 Design Process and Guidelines, [21] and Volume 2 Technical Guidelines [22]
- Clearing Our Path: Creating Accessible Environments for People with Vision loss [197]
- ETS Graphic Standards Manual: LRT Signage, Light Rail Transit
- ETS Brand Guide: Visual Identity
- Commissioning Consultant Manual, Volume 1 Whole Building Commissioning and Process Guidelines [19]
- Commissioning Consultant Manual, Volume 2 Building Envelope Commissioning and Process Guidelines [20]
- Crime Prevention Through Environmental Design (CPTED) Principles [198]
- Parking Structures Planning, Design, Construciton, Maintenance and Repair [199]
- City of Edmotnon Road and Walkway Lighting DesignManual [200]

- City of Edmonton Light Efficiency Community Guidelines [53]
- Climate Resilient Edmonton: Adaptation Strategy and Action Plan [55]

10.2 STATION CLASSIFICATION SYSTEM

The initial location of new Stations is assessed during a project's concept planning phase and considers adjacent land use, transportation networks, track alignment requirements, the Owner's transit-oriented development policy, potential constraints for land acquisition, projected ridership data, environmental factors, and relevant City guidelines and policies.

Based on an analysis of these factors in conjunction with the Station Classification Table provided below, the Designer must confirm Station specific programming requirements with the Engineer during the preliminary design stage.

The City of Edmonton Transit Oriented Development (TOD) Guideline [23] is an urban planning document that classifies Station sites into specific categories relating to key land use and site development considerations. The TOD guideline and these Guidelines are intended to be compatible and complementary. The TOD guideline is not meant to provide specific direction on Station or Platform design requirements.

10.2.1 Station Classification

10.2.1.1 Station Types

The Station classification system groups Stations into two functional categories: local and multi-modal.

Local - A local Station belongs to a specific area or neighbourhood. This Station is typically used only to embark or disembark and has limited transportation connections. At minimum, accessible connections to the Shared Use Path (SUP) or bicycle network, paratransit laybys, Patron drop off areas, and bus stops must be provided to service the surrounding neighbourhood. Minimum Design requirements for components and amenities at local Stations are provided in Table 10.1 – Station Classification.

Multi-Modal - A Multi-Modal Station provides significant connections to other modes of transportation. In addition to all the connections required for local Stations, Multi-Modal Stations add connections to bus Transit Centres and/or other LRT Stations. A Multi-Modal Station may also have direct connections to major urban amenities. A Multi-Modal Station may be further described by one or more of the following.

Downtown Stations – have an abundance of multi-modal options available within walking distance of the Station. Typically land use varies within the downtown area, but may include civic centers, employment, mixed-use residential, and urban parks.

Destination or District Stations – are designated primarily to service education, employment, healthcare, recreation, commerce, or event facilities. A district Station is typically a chosen destination by Patrons using the LRT System.

Terminus/Transfer Stations – are designated primarily for the purposes of transferring from one mode of transportation to another such as Transit Centers, Park and Ride facilities, or other regional transportation systems. A Terminus may also require end-of-line amenities for Patrons and Train Operators (TO).

Multi-Modal Stations must meet the minimum design requirements for local Stations, plus additional amenity or service requirements as determined by the Engineer and the Designer. Refer to Section 10.6.6 for further information on these requirements.

10.2.1.2 Multi-Modal Interchange

Required Station program and facility amenities vary depending on the types of multi-modal interchange functions at a specific Station. For example, if a Station is near a bus Transit Centre, additional plaza or circulation space may be needed to create a hub for Patron connectivity. Increased capacity for heated waiting shelters may be needed to support peak demand times, and public and transit operator washrooms may be required. Multi-modal interchange functions support the use of the LRT System by improving the connectivity to Stations, by providing amenities to enhance Accessibility, security, safety and comfort for Patrons, and by considering the urban design and landscape features that form part of the access route to the Station.

Refer to Chapter 14, Urban Integration for the specific design requirements of multi-modal transportation interchange functions and LRT bus replacement service.

Table 10.1 on the following page lists the requirements for inclusion of multi-modal interchange functions at Stations and the associated program components and amenities.

10.2.1.3 Station Components and Amenities

The minimum required Station components and Patron amenities as outlined in Table 10.1 on the following page must be included in all local and Multi-Modal Station Designs. Additional amenities may be required for Multi-Modal Stations based on an analysis of:

- The various modes of accessing Stations, which may require bicycle facilities (shelters, racks, or bike repair equipment), illuminated pedestrian pathways, bus facilities for transit Patrons, or Park and Ride facilities (refer to the City of Edmonton Park and Ride Guidelines [196]).
- The specific site context or projected ridership which may require additional amenities for neighbourhood - Station integration, such as plaza areas with site furnishings, pedestrian scaled lighting, or landscape features.
- Advertising, customer information, wayfinding or additional equipment, as directed by the Engineer and the Operator.
- Operations and Maintenance (O&M) requirements, including considerations for LRT replacement bus service, as well as Station and track maintenance activities.
- Additional program requirements for Patrons or transit operators, as directed by the Engineer.

Table 10.1 Station Classification

Station type	Transportation mode	Station components and amenities
Local	Category includes all active modes, public transit users, and other Patrons accessing Stations via: SUP Cycle track Bus stop Drop off laybys (Kiss & Ride/taxi/ride share) Paratransit priority loading areas	Platform Shelter Furniture Fare equipment Safety and security infrastructure Signage and branding Wayfinding and Passenger information Service vehicle access Marshalling cabinets Bicycle facilities (racks) Vacuum room or rough-in at Stations with ballasted track Water and sanitary service requirements if required
Multi-Modal	Category includes access to Stations via the transportation modes listed above as well as connections to: Bus Transit Centres Park and Ride facilities Regional bus or rail facilities	All components and amenities required for Local Stations in addition to the following: Advertising and non-fare revenue opportunities (ATM, kiosk, vending) Staff rooms Additional ETS branding (clock tower) Washrooms Service rooms Bicycle facilities (shelters, repair facilities, storage)

10.3 DESIGN PRINCIPLES

Urban Style LRT is intended to promote a range of integrated urban planning and design strategies that place emphasis on Accessibility, safety, convenience, comfort, Urban Integration and active mode connectivity throughout the Station area. Stations must integrate with their surroundings through Station designs and waiting amenities that are appropriately scaled to the surrounding urban realm, while considering anticipated ridership, adjacent land uses, and the intended mode of LRT.

Existing circulation patterns of motor vehicle and pedestrian flows and the effect of adjacent land use patterns must be analyzed during Station design to minimize disruption to existing neighbourhoods, consider pedestrian desire lines, and improve or maintain connectivity within the community.

Architectural Design of Stations must reflect the attributes of simplicity, economy, functionality, beauty, marketability, serviceability and safety. In addition, Designs should use a family of Station parts and amenities that are interchangeable but also allow for the retention of the individual character of the surrounding neighbourhood. Individual Stations should be recognizable entities to Passengers through the use of different colours, finish materials or some variation in configuration. Civic architecture must exemplify permanence, functionality, and character while maintaining the ETS brand logo identity and overall LRT System recognition.

Standardization of Platform layout, barriers and delineation, signage, Smart Fare Vending Machines (SFVM), clock towers, elevators, escalators, wayfinding, and other finishes assists Patrons in their use of the system and develops economies of scale for O&M.

Patron comfort is an integral element of Station design. The environment for Patrons in a Station must not only be safe and secure, but must also be enjoyable, comfortable, Accessible, and informative. Station design should protect Patrons from adverse weather conditions by providing seating at shelters and other protected locations on the Platform.

Materials used for Station architecture, both interior and exterior, must be durable, easy to maintain and should minimize life cycle maintenance costs. Methods of construction, materials, and products selected for projects must reflect the service and design life stated in Chapter 1, General. The use of glazing is discouraged wherever possible in areas outside of Platforms. When locating glazing, the Designer must balance maintenance and replacement challenges with safety, visibility and other benefits.

Station lighting can have a substantial impact on the quality of the Patron experience and their real and perceived safety. The chosen lighting colour spectrum should be as close to natural light as possible to bring out the true colour of objects. Lighting must be constant, uniform, and diffused, and glare must be minimized. Lighting, particularly interior lighting, should be instant-on to enable immediate recovery after a power outage. The lighting Design must promote safety by identifying and properly illuminating areas and elements of potential hazard. Light migration into nearby private property must be minimized, and all lighting must be in accordance with the City of Edmonton Light Efficiency Community Guidelines [53]. Designers must consider the potential short circuiting of electrical equipment and devices from all sources, including unexpected paths such as embedded baseplates, and reduce the risk of short circuiting wherever practicable. Refer to Chapter 11, Electrical for further information.

Light fixtures and standards should be incorporated into the architectural elements of the Stations as much as practicable. City Policy #C532 [10] should be applied, where applicable and practicable.

For specific lighting and illumination requirements for Platform edges, shelters, seating areas, fare collection equipment areas, ramps and stairs, LRT and bus loading areas, pedestrian walkways and crossings, parking areas, and wayfinding, refer to Chapter 11, Electrical and Chapter 15, Safety and Security. Illumination levels and system descriptions are provided in Chapter 11, Electrical for normal, emergency, and egress conditions.

10.3.1 Accessibility

The Designer must adhere to City Policy C602, Accessibility for People with Disabilities [54] and the City of Edmonton Access Design Guide [37] when designing Stations and Ancillary Facilities, and must also consider any additional codes or guidelines that may apply in accommodating the needs of persons with physical, sensory, and cognitive Disabilities.

The Designer should be proactive when applying Barrier-Free design solutions to provide persons with physical, sensory, intellectual, learning, communication, and mental Disabilities the same reasonable access to facilities as those who are able-bodied. Designers should not wait for changes to codes, standards or guidelines to apply these best practices.

Stations, and their approaches, must facilitate Barrier-Free movement of Patrons to and from the Station and other transportation modes. Pedestrian facilities must be well lit, distinguishable, and Barrier-Free.

The Design of Stations must include Barrier-Free access routes and emergency exits. Guidance Tactile Walking Surface Indicators (TWSI) must be used to provide wayfinding to Platform access points such as elevators, escalators, ramps, and stairs. Refer to Chapter 14, Urban Integration for information on guidance TWSI leading to Platforms.

Elevators must be provided where the provision of ramps cannot be reasonably accommodated. The Designer must provide sufficient designated wheelchair waiting and circulation areas to meet the projected demand and must provide high contrast signage to aid wayfinding for Patrons with visual impairment meeting the requirements of Section 10.7.4. At least two Barrier-Free entrances must be provided at every Station, and audio and visual Train arrival announcements must be provided.

Platforms and shelters should be provided with a variety of seating, some of which must include seating with backs and arm rests. Refer to Section 10.7.1 for more information.

Station Designs should consider using general layout features common to the LRT System to enhance Patron familiarity with Platform access and design features. The City of Edmonton Corporate Accessibility Committee (CAC) should review the Design as it is developed. Refer to Chapter 1, General.

Barrier-Free Accessibility must be integrated into requirements for all LRT circulation components, clearances, equipment, vehicles, and furnishings, wherever relevant.

10.3.2 Patron Safety

The following general safety and security principles provide guidance in the design of Platforms, Station areas, and access routes to enhance Patron safety and discourage vandalism and crime.

The design of Stations and other passenger facilities should have sufficient transparency and openness and must consider CPTED design principles to:

- Provide adequate visual surveillance, aiding Patrons in their awareness of the surrounding environment through unobstructed sight lines
- Provide the ability for others to see them, so that the feeling of isolation is reduced
- Provide adequate and appropriate lighting
- Avoid or minimize confined or hidden areas

Security features such as emergency telephones and Closed Circuit Television (CCTV) surveillance cameras must be an integral feature of the Station design and Station-related public areas.

The Designer must provide a report that identifies how CPTED [47] principles are incorporated into the design of the Station and all Station-related public areas, which will be reviewed by Engineer during design.

Patron safety and security requirements are presented in greater detail in Chapter 15, Safety and Security.

10.4 EMERGENCY EGRESS/EXITING

10.4.1 National Building Code - Alberta Edition (NBC-AE)

Emergency egress from Stations or Ancillary Facilities must conform to the latest edition of the NBC-AE and must be reviewed and approved by the AHJ. The Designer must review the exiting strategy with the Engineer and the AHJ during detailed design.

In general, application of the technical provisions of the NBC-AE to LRT facilities is clear. However, emergency egress from Platforms can be complicated by the requirements of the use and occupancy regulations, and other life safety system requirements such as ventilation. These regulations cannot be directly applied to transit facilities due to the following constraints:

- Definition of occupancy loads and the resulting units of exit width
- Exit lengths from Platform level to grade level may not be defined
- Presence of lead-end conditions on Platforms
- Use of tunnels as emergency exits
- Use of open stairways as exits from Platform level
- Requirements for persons with disabilities
- Provision of access for Fire Rescue Services (FRS) and Emergency Medical Services (EMS) personnel
- Recognition of the special security measures that are required in LRT facilities

10.4.2 NFPA 130 Standard for Fixed Guideway Transit System

Given the constraints of the NBC-AE [13] as discussed above, the Designer must review the NFPA 130 [17] documents due to their general acceptance by the North American transit industry with respect to fire safety issues. More specifically, NFPA 130 [25] provides guidance in calculating occupant loads in Stations, based on the emergency condition requiring evacuation of Trains and Station occupants to a point of safety.

NFPA 130 [25] considers multiple factors in determining the requirements for egress, including peak Train loads, headways, Platform width, the walking time of Patrons, and the presence of stairs, ramps, corridors, and other equipment. The Designer must provide the Engineer with an analysis demonstrating that the Design of the Platforms and Stations is able to meet the minimum requirements for means of egress as determined in the NFPA 130 [25] reference standard.

NFPA also address emergency ventilation systems used to meet requirements for a fire emergency in Stations, tunnels, and underground areas. Refer to Chapter 12, Mechanical for additional ventilation requirements.

10.4.3 Emergency Egress

10.4.3.1 Egress into LRT ROW

When the Designer determines that additional ramps or stairs intended for emergency egress only are required to allow Patrons to exit into the LRT ROW, the exit must be secured by a gated barrier to discourage general use by the public. A gate centered at the end of the Platform should be used rather than a swinging gate at the edge.

10.4.3.2 Special Exiting Considerations in Underground or Grade Separated Structures

Commercial areas that are planned for incorporation into any LRT facility must include fire separation from the adjacent Station areas as per the requirements of the NBC-AE [13]. In addition, commercial or retail areas must independently meet all relevant code requirements.

Special attention must be given to emergency exiting with respect to underground public retail or commercial areas. Exits are permitted to converge in fire-protected corridors or zones provided that the units of exit width are maintained for each occupancy. Due to design limitations imposed on an underground structure, ideal locations for exits at Street level on City owned property are not always available.

In cases where exit routes are in or on private property, the following criteria must be respected:

- Access agreements must be entered into between the property owner and the City
- Exit rights must be maintained during Station or underground commercial operating hours
- If redevelopment occurs, temporary exits must be provided until permanent exits are in place in the new facility
- Exit rights and agreements cannot expire on change of land or building ownership
- Appropriate cost sharing agreements must be established where appropriate
- All agreements affecting the NBC-AE [13] requirements must be irrevocable
- Security must be maintained for both the Station premises and the privately-owned property
- The NBC-AE [13] must not be violated by any changes to structure location, mechanical systems, and electrical systems

10.4.3.3 Emergency Egress Lighting Requirements

Illumination levels for emergency and egress conditions for interior and exterior locations are provided in Chapter 11, Electrical. Refer to Chapter 15, Safety and Security for CPTED requirements.

10.5 STATION ACCESS & PEDESTRIAN CIRCULATION

In addition to meeting the Station egress requirements as noted above, Station entrances must be designed to minimize queuing and consider bi-directional flow of Patrons to and from Platform areas. If doors are required, door widths must be designed to avoid congestion. All ramps, stairs, and passageways (including escalators and elevators, if required), must provide safe, Accessible, convenient, and direct access to and from the Station.

Notwithstanding the requirements of NFPA 130 [25], the Platform size, circulation routes and clear paths of travel must be designed to meet the projected demand and potential crush loads as determined by the Engineer.

The Designer must provide a minimum of two points of access to every Platform. A minimum of two access points to a Station must be Barrier-Free. Patron circulation routes providing access to Stations and Platforms must be direct. Disorientating turns, blind corners, unnecessary barriers, bottlenecks, and areas of congestion must not be part of the Design.

Cross flow of Patrons should not be created, particularly at fare vending and validation areas and at decision points. The Designer should provide adequate space to preclude queues at fare collection areas from blocking Patron flows, and should not create dead-ends and unnecessary turns.

Surge and queuing spaces must be provided ahead of every barrier and where there is a change in direction or circulation, or a modal transfer. The Design should locate passageways, shelters, and stairways to encourage balanced Train loading and unloading. Interior floor finishes should define circulation routes using flooring materials differentiating in colour and texture. Heavily patterned floors should not be used, especially in areas where there are elevation changes.

Elevators and stairs must be provided to Grade Separated Stations, even if escalators are present. Access between Station levels must be via an interior elevator or ramp. Reliance on exterior walkways to access other interior levels does not meet the intent of the NBC-AE [13]. Specific requirements for access routes between Stations and other ETS public transit facilities are provided in Chapter 14, Urban Integration.

10.5.1 Off-Platform Surge, Refuge, and Queuing Areas

10.5.1.1 Public Areas

Area for Patrons and pedestrians at waiting or queueing locations must be provided to accommodate the projected ridership and any anticipated crush loads at the following locations:

- Platform access points that meet or intersect with a pedestrian Street and/or a LRT ROW crossing point
- Crossing midpoints to either access a Platform or wait for the next safe crossing opportunity
- Fare collection and validation locations

Where a Platform is accessed from a pedestrian crossing in a center-running configuration, the ramps or sloped walkways between the crossing and Platform must be designed to provide a safe area where exiting and arriving Patrons are protected from motor vehicles and the LRT ROW. In addition, adequate area must be provided to accommodate waiting and queueing pedestrians using the crossing facilities during a non-pedestrian signal phase. At a minimum, this area should encompass the full depth of the pedestrian crossing and the full width of the sloped walk. The pedestrian crossing portion of the area may either be at roadway level, to avoid grade changes through the Street and rail crossing, or may be at top of curb elevation with curb crossing ramps to roadway and track level.

The Designer must provide an analysis of the requirements for queuing and surge areas based on projected ridership, requirements for timed exiting as per NFPA130 [25], the NBC-AE [13], and the City of Edmonton's Access Design Guidelines.

Refer to Chapter 3, Clearances and Right-of-Way for Platform horizontal and vertical clearance requirements and to Chapter, 17 Streets, for additional pedestrian crossing requirements.

10.5.1.2 Refuge Zones and Designated Egress Walkways

Refuge Zones and Designated Egress Walkways must provide safe movement for both ETS personnel and for Patrons in an emergency. The Designer must review all refuge and egress requirements with the Engineer and Operator during the preliminary design stage. Any infrastructure that services the Platform or the Trackway must not be located within the refuge zone with the exception of galvanized steel vacuum outlets.

Emergency egress must satisfy the requirements of NFPA 130 [25]. Refer to Chapter 9, Structures for Refuge Zones within tunnels.

10.5.2 Station Head, Concourses & Connecting Links

10.5.2.1 Station Head

Grade Separated Station facilities in underground, trenched and elevated trackway locations must include Station head infrastructure to provide transitory spaces that include all necessary vertical and horizontal circulation infrastructure to allow Patrons to safely and efficiently enter and exit the Station. In addition to vertical circulation (stairs, ramps, escalators, and elevators) and their associated surge spaces, Station heads may also accommodate service and equipment rooms, fare processing areas, Patron washroom facilities, and commercial retail units or kiosks.

10.5.2.2 Concourses

A Concourse that provides Patron circulation and access/egress may be a primary design component of Station heads. Typically, Concourses are situated one level below Platform level in Elevated Stations, and one level above Platform level in underground Stations. Concourses in underground Stations may link the Station to an underground pedway system at the same level or to ground level. Concourse levels in these locations typically accommodate fare processing and vertical circulation elements between the Platform and Concourse and their associated surge spaces.

Station head and Concourse elements may be configured for center or side-loading Platform layouts and must consider the design of the facility in terms of Patron safety, LRT operations, adjacent land use, and SUI principles.

10.5.2.3 Connecting Links

Connecting linkages into or within a Station are typically passageways or corridors that are internal to Stations or pedways. Pedway structures generally connect to Station entrances or directly to the Platform and can either be elevated or below-grade.

The width of passageways for public use must be determined by the calculation for the exiting requirements as governed by the NBC-AE [13] and NFPA 130 [25]. In the case of a conflict between NBC-AE [13] or NFPA 130 [25] and this guideline document, the requirements providing the greatest clearance must govern. The minimum acceptable width of non-exit, passageways for non-public use is 900 mm. For public use pedways the passageway width (exiting width) must be determined by the requirement to meet a point of safety within six minutes, as per NFPA 130[25], but not less than 4000 mm. The minimum clear height must not be less than 2800 mm, excluding fixtures such as lights, directional signage, and other required installations.

Refer to Chapter 12, Mechanical for heating and smoke ventilation requirements.

10.5.3 Vertical Circulation

Each Station will have specific vertical circulation requirements based on Station type, access requirements and grades established as part of the overall site plan. Access to Stations and Ancillary Facilities must be Barrier-Free using ramps and/or elevators in addition to stairs and escalators.

The location of ramps and stair entrances are a function of Street infrastructure, adjacent land use, property ownership, and Station external and internal integration requirements.

10.5.3.1 Ramps

At minimum, all ramps must meet the requirements of the NBC-AE [13] and the City of Edmonton Access Design Guide and the Barrier Free Design Guide [195]. The clear distance between handrails must consider the need for motorized snow removal equipment on exterior ramps and must be a minimum of 900 mm wide. The Designer must confirm specific requirements with the Operator.

10.5.3.2 Stairs

At minimum, all stairs must meet the requirements of the NBC-AE [13], the City of Edmonton Access Design Guide [37] and Barrier Free Guide [36]. Open risers are not permitted and nosing of stairs must be of a contrasting colour with respect to the treads and risers. Tread nosing must have either a radius or a bevel between 8 mm and 13 mm in the horizontal dimension. Refer to Figure 10.1 in Appendix 10B.

Continuous railings must be provided on both sides of stairs. Step run should be 305 mm and step rise should be 165 mm. The front edge of stair treads in exits and public access to exits must be at a right angle to the direction of exit travel. A 100 mm wide sweep or cleaning trough on both sides of interior stairways should be considered for ease of cleaning.

Bicycle wheel ramps a minimum of 310 mm wide must be provided along one side of all stair locations. This is of particular importance for active mode connections to Grade Separated Stations. Refer to the City of Edmonton Access Design Guide [195] for further information.

Where escalators are provided, stairs adjacent to an escalator must be parallel to the angle of inclination of the escalator and sized to have landings at a common level.

10.5.3.3 Railings

At minimum, all railings must meet the requirements of the NBC-AE [13], the Barrier Free Design Guide [36] and the City of Edmonton Access Design Guide [37]. Handrails should be terminated by returning the ends into a wall or downward to reduce the possibility of catching clothing on the ends of the handrail. Railings on interior and exterior stairs must be stainless steel or galvanized steel. Other low maintenance finishes and coatings may be acceptable upon approval of the Engineer.

Railings must be provided at Platform ends, set back a minimum of 300 mm from the edge of the Platform, or the minimum width required to provide clearance to the dynamic envelope, whichever is greater. Vertical railing supports should be welded flush to preinstalled embedded anchor plates.

10.5.3.4 Escalators

At minimum, all escalators must meet the requirements of the Alberta Safety Codes Act (ASCA), including the NBC-AE [13] and the Alberta Elevating Devices and Amusement Ride Safety Association (AEDARSA). Escalators must also meet the requirements of the Safety Code for Elevators and Escalators [186] and should comply with the American Public Transportation Association (APTA) Heavy Duty Transit Escalator Design Guidelines [187].

Escalators must be included in Station Designs based on consideration of the following conditions and design criteria:

- Exiting requirements as governed by NBC-AE [13] and NFPA 130 [25]
- The total vertical rise to be travelled
- The type of operating environment and the potential for on-going maintenance issues

For fully enclosed underground Stations the Designer must provide two escalators from Platform to Concourse level and at least one escalator from Concourse to Street level.

For other Grade Separated Stations, the Designer, in consultation with the Engineer, must determine the total number of escalators to be provided based on site conditions, the total vertical distance to be travelled, entrance/exit locations, interior circulation, and exiting requirements.

Where escalators are provided, they must be at an angle of inclination that does not exceed 30º from horizontal and have running headroom not less than 2200 mm. Escalators must have a Patron activated emergency control at the top and bottom of the escalator run, be capable of operating with a full load at a speed of 27.5 m per minute, and be equipped with an anti-rollback feature.

Any equipment that is installed at a Station must not require a climbing device on an escalator to operate, maintain, or replace the equipment.

Although escalators are restricted to operate in one direction only, they must be designed for bi-directional operation complete with necessary supporting equipment/control as required by AEDARSA. New escalators must be keyed to match existing escalators in the LRT System.

A stainless-steel handrail or emergency guard must be mounted on the balustrade on the outside of the escalator handrail (refer to Appendix 10B Figure 10.2). Glass walled escalators are not permitted.

10.5.3.5 Elevators

At minimum, all elevators must meet the requirements of the ASCA, including the NBC-AE [13] and AEDARSA, the City of Edmonton Access Design Guide [37], and the Safety Code for Elevators and Escalators [186].

In general, the incorporation of elevators into the design of Stations must be based on requirements for Barrier-Free access. In Stations where Barrier-Free access to Platforms can be reasonably achieved with ramps, elevators are not required unless otherwise directed the Engineer. Where it is practicable and necessary to provide an elevator for Barrier-Free access to Platforms, a minimum of two elevators must be included at each Station to increase flexibility for provision of access during maintenance. The requirement for additional elevators is dependent on entranceway, interior circulation and Barrier-Free Accessibility requirements. Elevator access locations should be as weather protected as practicable.

The following requirements must be provided by the Designer when designing elevators:

- A minimum capacity of 1134 kg
- Minimum inside dimensions be 2032 mm x 1295 mm
- Access control provided from the Security Operations Control Centre (OCC)
- The use of graffiti-resistant finish materials in the cab interior
- At least one transparent side in the elevator car at each stop position
- Flooring meeting the Operator’s requirements for maintenance, durability, and slip resistance
- Lighting covered with a protective transparent shield to limit vandalism
- Machine rooms, if required, in close proximity to the elevator and must be acoustically treated to minimize noise
- Oil heaters installed in hydraulic elevator storage tanks if the elevator is not in a heated area
- A self-recharging battery pack to maintain lighting and return the elevator to its lowest landing, open the doors, and render the elevator inoperative in the event of a power failure
- A sleep mode function
- All elevator keying matching the keying of the existing elevators within the LRT System
- Elevators equipped with “Home” interface for fire alarm system input signal as per the requirements of Chapter 11, Electrical
- All electrical & mechanical systems in conformance with AEDARSA
- A telephone connected with the ETS Voice over Internet Protocol (VoIP) System for emergency communication to the Security OCC must be provided as follows:

  - The telephone must not be located at a mounting height lower than the lowest control push buttons and no higher than 1220 mm from the floor
  - The telephone cabinet may be located opposite the control push buttons
  - The telephone must be identified by the international symbol for telephones in a contrasting colour, with the symbols at least 38 mm in height and raised at least 0.75 mm
  - The telephone must be equipped with a volume control

- The operating status of the elevator is to be monitored by the Building Management System (BMS). Refer to Chapter 12, Mechanical for BMS requirements
- Refer to Chapter 11, Electrical, for fire alarm and lighting level requirements for the interior and exterior of elevators and at control panel locations
- Elevator doors must begin to close a minimum of 8 seconds after reaching the fully-open position

10.6 STATION DESIGN

Stations may be in either centre-running or side-running LRT corridors and be either At-Grade or Grade Separated. For Urban Style Stations, where there is a greater emphasis on pedestrian access, side-running track alignments and side-loaded Platform configurations allow for better Station integration into adjacent sidewalk and plaza areas.

The following Station types are typical for the LRT System.

10.6.1.1 Side-Loaded Staggered Stations (At-Grade)

Side-loaded staggered Stations consist of two side-loaded Platforms offset on either side of a vehicle or pedestrian intersection. Patron access is provided from the nearest intersection crossing or from mid-block crossing locations to an end of the Platforms. Side-loaded staggered Stations are only feasible for centre-running LRT corridors.

10.6.1.2 Side-Loaded Facing Stations (At-Grade)

Side-loaded facing Stations consist of two parallel facing, side-loaded Platforms. For a side-running alignment, direct Patron access is provided from the adjacent sidewalk or plaza for one Platform. Alternatively, patron access is provided from the nearest intersection crossing or from mid-block crossing locations to an end of the Platforms.

10.6.1.3 Centre-Loaded Stations (At-Grade)

Centre-loaded Stations consist of a single At-Grade, centre-loaded Platform between the LRT tracks. Patron access is provided from the nearest intersection crossing or from mid-block crossing locations to an end of the Platform.

10.6.1.4 Grade Separated Stations

Grade Separated Stations are either above- or below-grade Platforms in either a side-loaded or centre-loaded configuration. Grade Separated Stations can be further categorized as described below.

Underground Stations – are located in completely enclosed spaces below ground level. Underground Stations are accessed through a Station head and typically include a Concourse level with connecting links.

Trenched Stations – are located below grade but are shallow open-air structures. Trenched Stations are accessed through a Station head and may include heated spaces.

Elevated Stations – are located above-grade and are open-air structures. Elevated Stations are accessed through a Station head and may include a Concourse level.

Underground Stations have additional requirements for the design of a smoke removal system and require extensive coordination with the Engineer, the Operator, Emergency Medical Services (EMS), and Fire Rescue Services (FRS). The smoke ventilation system must meet the requirements of the NBC-AE [13] and NFPA 130 [25].

Refer to Chapter 12, Mechanical for tunnel smoke ventilation and detection system requirements.

10.6.2 Platforms

The type of Platform configuration and its specific location along the LRT alignment is determined during concept planning in conjunction with the overall planning approach for Station type and the degree of neighbourhood integration desired. As each Station is unique, the specific requirements for each Station and Platform are determined through the Station classification system described in Section 10.2, and in consultation with the Engineer and Operator.

10.6.2.1 Platform Configuration

Platforms can be either centre loading or side loading. A centre loading Platform is generally preferred over side loading Platforms because of the efficient and flexible access options and the accommodation of cross-Platform Patron movements. However, ROW space constraints and a desire for improved neighbourhood integration may lead to the use of side loading Platforms.

The size and configuration of a Platform is defined by the length of a Train, Patron loading requirements, egress/exiting requirements as per NFPA 130 [25], projected ridership, and constraints on available LRT ROW.

10.6.2.2 Platform Length

Platform length must be a minimum of 125 m, but when space constraints (e.g. distance between intersections) or land acquisition challenges preclude this the Engineer and Operator may consider a reduced Platform length to an absolute minimum of 123 m. This length is based on five Light Rail Vehicle (LRV) Consists. Staged implementation of Platforms where only shorter Consists are accommodated for a period of time may be considered in consultation with the Engineer and the Operator.

Accommodating high Patron volumes, particularly at Stations serving large event facilities may require Platform lengths up to 130 m. Platform length must be discussed and confirmed with the Engineer and Operator early in the design process.

10.6.2.3 Platform Width

A primary outcome of the Station classification analysis is the determination of the appropriate Platform width to support the programming requirements for each unique Station. The Designer must demonstrate that the Platform width provides the following:

- Sufficient space for shelters, equipment, and amenities placed in the centre portion of the Platform for centre loading Platforms
- Sufficient space for shelters, equipment, and amenities placed adjacent to the back wall/edge of the Platform for side loading Platforms
- A tactile warning zone 915 mm wide continuously along the Platform edge (refer to Section 10.6.2.8 and Appendix 10B Figure 10.3, and 10.3A)

- Accommodation of all Barrier-Free clearances as described in the City of Edmonton's Access Design Guide
- Inclusion of a Barrier-Free (1800 mm x 1800 mm minimum) priority waiting area, defined by a contrasting floor area and signage with locations for priority areas
- Conformance with egress/exiting requirements as described in Section 10.4, which uses NFPA 130 [25] in calculating occupant load and exiting width
- A minimum width of 1800 mm for Station egress ramps, notwithstanding the exiting and Barrier-Free requirements indicated above

10.6.2.4 Platform Height

The finished Platform height above Top of Rail (TOR) for all Station types must be 890 mm +5/-15 mm. Refer to Chapter 3, Clearances and Right-of-Way.

10.6.2.5 Platform Clearances

Horizontal and vertical clearance guidelines are provided in Chapter 3, Clearances and Right-of-Way, based on the Design Vehicle Dynamic Envelope (DVDE).

10.6.2.6 Catenary Clearances Above Track

The minimum vertical clearance distance is governed by the Overhead Contact System (OCS) clearance requirements as described in Chapter 6, Traction Power.

For minimum distances between the TOR to the underside of the catenary contact wire refer to Chapter 3, Clearances & Right-of-Way and Chapter 6, Traction Power.

The Station Designer must coordinate with the OCS Designer to confirm that the catenary height requirements can be met at approaches to and throughout the Station area. This is especially important where road crossings are located immediately before or after a Station, where the OCS may transition in height.

10.6.2.7 Platform Drainage

Where Platforms are within a fully enclosed structure, the finished Platform surface may be flat. The longitudinal grade must match the track grade. Refer to Chapter 4, Track Alignment.

For Platforms that are not fully enclosed or are only partially covered, the finished surface must slope at 1.5% toward the Trackway. For centre loaded Platforms, the crown of the slope is in the centre of the Platform.

10.6.2.8 Platform Floor Finish

Platform floor finishes must minimize the risk of injury to the public and avoid the need for excessive maintenance. Slip resistance requirements are provided in Section 10.12. The Platform floor colour and texture must be different from the floor surfaces in the areas approaching the Platform.

A 915 mm wide TWSI strip measured from the edge of Platform must be provided. This warning strip consists of 300 mm wide, anti-slip ribbed texture placed along the trackside edge of the Platform and a 610 mm wide Americans with Disabilities Act (ADA) [6] compliant truncated dome detectable warning surface (Appendix 10B).

Guidance TWSI that provides wayfinding to Platform access points is discussed in Section 10.3.2 and in Chapter 14, Urban Integration.

10.6.2.9 Service and Maintenance Access

A minimum of two parking stalls for Service Vehicles must be provided at each Station in close proximity to a Station entrance. The parking stalls must be a minimum of 2600 mm wide by 5500 mm long, hard surfaced, and all-weather trafficable from the adjacent Street.

Access from the Platform to track level must be provided at each end of the Platform, however, access requirements may vary depending on the Station type and Platform configuration. The Designer must review required maintenance access to the Trackway with the Operator during the preliminary design stage.

10.6.2.10 Platform Crawl Space

The underside of the Platform for all Station types must be designed to provide an accessible crawl space for inspection and maintenance. The height of the crawl space must be designed to align with the definition of a crawl space as per the NBC-AE [13]. A hatch or doorway at track level should be provided but may not always be practicable. Provision of manhole access from the Platform should be reviewed with the Engineer during the preliminary design stage. Adequate lighting and ventilation for routine maintenance and inspection must be included and must meet the minimum requirements of the NBC-AE [13].

The crawl space must include drains to collect any ingressing water and must have a concrete surface to reduce the potential for mold formation. Refer to Chapter 16, Utilities and Drainage and Chapter 9, Structures. When an unsprinklered crawl space is constructed beneath a platform, fire-blocking partitions must be provided as per the NBC-AE [13]. Access between each of the compartments may be provided via doors in the fire-block assemblies in lieu of providing access to each compartment through manholes in the station platform. Ventilation must be provided throughout the crawlspace at rates that meet or exceed those required by all applicable codes, reference standards, or any other criteria identified by the Engineer and in Chapter 12, Mechanical.

10.6.2.11 Platform Basement Level

Space limitations at some Stations may require a basement to house service areas. The placement of electrical and communication rooms in a basement is not acceptable unless the Design prevents water entry into the space.

10.6.2.12 Maintenance Corridors

Any path of travel which is provided to service or maintain equipment or Station elements is considered a maintenance corridor. These corridors should provide minimum clear width of 1000 mm and 3000 mm of height.

10.6.3 Canopies/Roofing

Canopies and roofing types may differ significantly for each unique Station. Continuous and complete coverage of outdoor Platform areas should be provided. Where only partial coverage is provided, sheltered enclosures with roofs for waiting Patrons must be provided. Canopy roofing must include:

- Provision of roof access for cleaning and maintenance
- Provision of snow stops where required
- Bird deterrent surfaces and/or minimal opportunities for bird roosting. Further consideration must be given for implementation of bird deterrence/dispersal systems. These systems must be designed in consultation with the Engineer and the Operator
- A soffit access hatch to match the requirements of NBC-AE [13], with no dimension less than 610 mm

The Design must include a climate-controlled building enclosure over the portions of the Platform that contain escalators, elevators, and service or Patron amenity rooms. The requirement for heated Patron waiting areas and stairways is to be reviewed with the Engineer. The Designer should consider the use of skylights to provide natural daylight to the Platform.

10.6.3.1 Fall Protection

The roof Design should not require fall protection and/or fall arrest systems. This may be accomplished by providing guardrails, or parapet walls of sufficient height. However, if the requirement for fall protection and/or fall arrest systems cannot be avoided, the fall protection system must be non-proprietary to permit installation, maintenance, or inspections to be performed by any qualified party contracted by the Owner.

10.6.3.2 Drainage

Roof assemblies must be designed to prevent ponding of water on the roof to reduce live loads and damage to the roofing assembly. Sloped roof structures should be used where practicable. Roof drain locations must be coordinated with all other Station components mounted on the underside of the roof. Heat traced gutters and down spouts for the roof drainage system, tied directly into a storm drain connection, must be provided. Refer to Chapter 11, Electrical for heat tracing details, Chapter 12, Mechanical for roof drainage systems, and Chapter 16, Utilities and Drainage for storm water management and conveyance requirements.

10.6.3.3 Canopy Lighting

Platform lighting requirements must be evaluated on a Station by Station basis and luminaires must be selected in conjunction with the specific architectural design requirements for integration and installation type, form, and serviceability. Lighting fixtures installed at the ceiling or underside of the roof structure that cast continuous lighting on the Platform edge warning strip must be provided. Exterior Platform Canopies must incorporate lighting tied to daylight sensors. The Designer should consider providing multiple lights wired on different circuits to control lighting levels and reduce required maintenance, however this must be evaluated alongside other requirements (e.g. safety, visibility). Architectural or accent lighting to enhance building features must meet the requirements for minimizing light pollution. The Canopy lighting system must be designed to accommodate various lighting zones to control dimming percentages based on individual areas, while minimizing glare to maintain the lighting levels presented in Chapter 11, Electrical.

10.6.4 Platform Shelters

Heated sheltered enclosures, designed to protect Patrons from wind, rain and snow, must be provided on all outdoor Platform areas. Doors are not required for shelters to promote ease of circulation and minimize maintenance. If included in a Design, automatic swing doors must provide at least a 15 second minimum delay before closing from the open position. Shelters must accommodate the required wheelchair turning radius as outlined in the City of Edmonton Access Design Guide [37].

Shelters may be designed to incorporate a vestibule or wind break for fare payment and ticket validation equipment. Alternatively, a separate, stand-alone vestibule area may be provided for this equipment. Where glass shelter walls are used, graphic visual film as per the City of Edmonton Access Design Guide [37] must be included in the Design. Additionally, standard glass sizes must be selected for ease of maintenance and facilitate replacement by two people.

The number of shelters required on a Platform and their size is dependent on the following factors:

- The degree of Canopy coverage over the Platform

- The orientation of the Platform to prevailing winds
- The proximity of the Station to an adjacent Transit Centre and the projected Transit Centre Patron loadings
- Whether Platform construction is to be staged
- The remaining Platform area available for Patrons, exclusive of signage, fare equipment, communication devices, and seating areas

10.6.4.1 Heated Enclosed Buildings

Depending on the functional program requirements and the configuration of the Station, heated, enclosed building structures may be required as part of the Station design. At entrances to Station buildings, and where space permits, the Designer should provide vestibules at main building entrances to control heat loss.

10.6.4.2 Radiant Heat

Overhead gas heaters should be provided as heating devices in shelters, however electric infrared heaters may be permitted. Any selection of heaters must align with the City of Edmonton's Climate Resiliency Policy. If gas heaters are selected, they must have burners that will resist wind blow-out. Heaters in shelters are to be provided with vacancy sensors, wave motion activators, and automatic thermostatic control by the BMS including manual override control. The Designer should also consider placing radiant heaters in other areas of the Platform, particularly near fare equipment.

Refer to Chapter 8, Communications and Chapter 12, Mechanical.

10.6.5 Design Coordination

The Station Design must achieve minimal visual clutter and distraction in and around Stations. Where practicable, the design of Stations should limit areas of exposed conduit, rainwater leaders, piping, gas lines, grounding wires, unnecessary signage, or surface mounted hardware through interdisciplinary coordination.

10.6.6 Station Service and Amenity Rooms

The Station classification system described in Section 10.2 outlines the minimum program requirements for a local Station type. Where multi-modal functions are integrated with Stations, or where the site-specific context dictates, additional services or amenities may be required, such as maintenance equipment storage areas, service areas, or washroom facilities. The need for additional facilities within Stations or on Platforms must be determined through discussion with the Engineer and Operator. Requirements for the Design of these facilities are provided below.

10.6.6.1 Patron Washrooms

Public washrooms must be provided at Terminus Stations, at Stations with Park and Ride facilities, and at Stations adjacent to a Transit Centre. A public washroom may not be required at an LRT Station if one is provided at an adjacent Transit Centre. Public washrooms are not a requirement at local Stations.

If public washrooms are required, a minimum of two, single occupancy, gender neutral, universally accessible washrooms must be provided.

Directional signage leading to public washrooms must be provided in accordance with the LRT Graphics Standards Manual. Washroom signs must be included on exterior entrance signs.

Washrooms must be heated. Refer to Chapter 12, Mechanical.

All washroom fixtures and accessories must meet the requirements of the NBC-AE [13], the Alberta Barrier Free Guideline [194] and the City of Edmonton Access Design Guide [195]. Additionally, the design of washrooms must meet the following Owner requirements:

- Floors and walls must be tiled
- Glossy or highly polished finishes are not permitted
- Washbasins should be built into a counter or vanity; washbasins located above the countertop must not be provided
- Hot water service must be provided
- Automatic water controls and flushers must be included
- Universal washrooms must be provided with both a toilet and a urinal
- A fold-down infant change table mounted on a wall inside of the washroom must be included
- Air hand driers and sanitary napkin disposal units must be provided for each washroom; paper towel dispensers must not be provided
- Sharps needle disposal units must be provided for the proper disposal of medical sharps
- All fixtures must be stainless steel and vandal-resistant
- A glass or polished metal mirror must be provided
- Coat hooks must be provided on the back of the stall / washroom door
- The Designer should consider the installation of self-cleaning toilet systems
- Consideration must be given to cleaning and extraction of foreign materials in the drainage system. Refer to Chapter 12, Mechanical
- Single occupancy washrooms must be lockable from the inside using a thumb latch that is equipped with an “Occupied/Unoccupied” indicator on the exterior face
- An exterior light fixture adjacent to a fixed sign, indicating whether the washroom is occupied must be provided near the washroom doorway and activated by motion sensor inside the washroom. Refer to Chapter 12, Mechanical for BMS requirements
- CCTV coverage of the exterior of the washroom entrance doorway must be provided
- Exterior lit “Occupied” signs must be visible to ETS security via CCTV
- A hands-free direct dial phone, connected to ETS security, must be located on the exterior wall near the washroom doorway for Patrons to request access
- A hands-free direct dial emergency phone, connected to ETS security, must be mounted on a wall of the washroom interior
- Locking and unlocking of all washroom doors must be controlled remotely by ETS security
- A power door opener must be provided to automatically open the washroom door once ETS security remotely activates the door release
- The automatic opener must not unlock the thumb lock used in single occupancy washrooms
- An automatic door paddle located inside the washroom beside the door must be provided
- A doorway presence sensor must be provided on all doors accessing the Patron Washroom, to prevent closing on an occupant. Doorway sensors and wiring must be integrated with the door and frame maximize vandal resistance.
- Automatic swing doors
- provide at least a 15 second minimum delay before closing from the open position

10.6.6.2 Staff Washrooms

Staff and Train Operator (TO) washrooms must be provided when ETS security staff, inspectors, or maintenance staff are housed at a Station and when a Station is designated as Terminus Station. For TO washrooms, a minimum of two unisex washrooms must be provided. Washroom requirements for fixtures and accessories are as per Patron washrooms above, with the following additions:

- A phone for the TO use must be provided inside the washroom
- A water spigot for drinking water must be provided inside the washroom
- An infant change table is not required in TO or staff washrooms
- Door entry is through card reader access

When a crew room is required at high-capacity Stations, washrooms must meet the following additional criteria:

- Separate male and female staff washrooms must be provided
- Male washrooms must provided two individual stalls and two urinals
- Female washrooms must provide two individual stalls
- Washrooms are not required to meet Barrier-Free requirements, however, if a food kiosk is present in the Station and there are no other public washrooms provided the washroom must meet Barrier-Free requirements
- Where toilet partitions are required, these must be floor mounted, steel panels, with a surface mounted dead bolt type stall latch
- Washrooms may be required to house a change area with lockers that are sized to allow winter clothing to dry.

The Designer must confirm the requirements for stalls and change areas with the Engineer and Operator during design.

10.6.6.3 Janitorial Room

Where a janitorial room is required for storage of cleaning supplies and related equipment, it should be located at Platform level. Inclusion of the following services and amenities must be considered and reviewed with the Operator during design:

- Electrical service for the charging of battery-operated portable equipment
- A fire alarm
- Water service
- Built-in shelving or cabinets
- Washbasin built into a counter or vanity
- Mop sink with appropriately sized backsplash
- Space for floor scrubber

Design consideration must be given for the provision of a lunch room for custodial staff. Additional consultation with the Operator must occur to confirm the project specific requirements

10.6.6.4 Security Patrol Room

If required, a security patrol room must be provided for the Owner's security staff to monitor Patrons within the Station as well as the Station non-public areas. This space is to function as an on-line workspace only, not a deployment location. The patrol room must accommodate up to four staff with workstations for computer, network and printer connections. The following amenities must be provided, unless otherwise defined by the Engineer:

- Service connections for a phone (VoIP) system
- Air conditioning with temperature control
- A fire alarm
- Windows with one-way glass
- Horizontal blinds on all windows

- Dimmable lighting
- Vinyl flooring
- A sink and vanity
- One microwave oven service connection
- Parking in close proximity to the Station for one Service Vehicle. This parking is additional to stalls provided for other requirements.
- Card reader access

10.6.6.5 Crew Room

Where a crew room is required, it must be a combined office/work/lunch room, accommodating up to six persons. This room will function as a deployment location. The following amenities must be provided, unless otherwise defined by the Engineer:

- One work table
- One computer workstation with computer and printer service connections
- Service connections for a phone (VoIP) system
- Vinyl flooring
- Service connections for a microwave oven and a small refrigerator
- Sink and vanity
- Eyewash station with dedicated water service
- Nearby secure storage for tools and materials, including gasoline powered equipment
- Heated and secured parking in close proximity to the Station for up to three Service vehicles (in addition to stalls provided for other requirements)
- Nearby heated parking (or exterior parking with plug-ins) for up to six staff
- Card reader access

10.6.6.6 LRT Inspector Room

Where an LRT inspector room is required, it must function as a combined office/lunch room, accommodating up to three persons. LRT inspectors will report to this room at the start of their shift. The following amenities must be provided, unless otherwise defined by the Engineer:

- Change area with lockers
- One computer workstation with computer and printer service connections
- A filing cabinet
- Service connections for a phone (VoIP) system
- Service connections for microwave oven and a small refrigerator
- Heated parking and secured parking in close proximity to the Station for one Service Vehicle (in addition to stalls provided for other requirements
- Nearby heated parking (or exterior parking with plug-ins) for two staff
- Card reader access

10.6.6.7 Vacuum Room

Vacuum rooms must be provided at Stations with ballasted track. At Urban Style Stations with no provision for service rooms on Platforms, the Design must include rough-in for vacuum piping lines and outlets only. Where rooms are required and can be accommodated, they must be large enough to house a central vacuum system. A separate room at Platform level should be provided to facilitate access for the track mounted equipment that will handle the dust collection barrels. The placement of electrical or communications equipment or panels in this room is not permitted due to the potential for dust spill-over.

The ceiling of the vacuum room should provide sufficient height to accommodate a hopper style tubular bag separator that straddles the dust collection barrels. The floor area of the room must allow for servicing and maintenance of the equipment from all four sides including space for an extra collection barrel. If adequate access space cannot be provided, access must be provided to at least two sides, subject to the manufacturer's verification of suitability.

Galvanized steel vacuum outlets must be provided at 20 m spacing under a Platform overhang. For centre-loaded Platforms outlets must be provided on both sides of the Platform. For side-loaded facing Platforms only one set of outlets may be required subject to approval by the Engineer.

Refer to Chapter 12, Mechanical for further information.

10.6.6.8 Snow Clearing Equipment

Janitorial storage space may be used to store snow clearing equipment if sufficient space exists. Otherwise, a separate storage area for snow clearing equipment should be provided. The location of this equipment must be coordinated with the Operator.

10.6.6.9 Other Maintenance

A secure storage room for spare parts and Contractor's materials and equipment must be provided. The Owner and Operator will jointly determine the location of a cash vault at a Station if required. The Operator will provide the Designer with detailed design and related installation requirements for storage rooms or cash vaults as required.

One tamper-proof water hose bib must be provided near the center of a Platform, unless otherwise defined by the Engineer. If a central location is not practicable, a hose bib must be provided at both ends of the Platform.

Refer to Chapter 11, Electrical and Chapter 12, Mechanical for additional information.

10.6.6.10 Storage

Additional storage may be required at stations for directional sandwich boards and other maintenance/operator equipment. Storage requirements for specific platforms must be coordinated with the Engineer and Operator.

10.7 FURNISHINGS, ART, AND EQUIPMENT

10.7.1.1 Station Furniture

Typical furniture placed in or near Stations include benches for Patron seating, leaning rails, and garbage/recycling receptacles. These installations should enhance the comfort and convenience for Patron, be functional and compatible with the Station design, be vandal and graffiti resistant, and be placed to not impede Patron circulation. All anchors attaching Station furniture must be stainless steel to resist corrosion.

The Designer must develop Station furniture requirements and layout for coordination with the Operator early in the design of the project, prior to specification development.

Station furniture, particularly garbage and recycling receptacles, should not be located near fare equipment.

10.7.1.2 Benches & Leaning Rails

Platform benches must be provided and must be durable and maintenance free. Benches should be of metal construction. Seating must provide options for end and intermediate armrests and backrests to enhance Barrier-Free Accessibility as per the City of Edmonton Access Design Guide.

Benches should be designed to discourage loitering, laying down, and skateboarding and must be vandal resistant. The location of Platform seating and leaning rails should not interfere with Patron circulation or access to overhead lighting and equipment.

The seating type and capacity, including spaces required for wheelchairs, must be developed by the Designer in consultation with the Operator.

10.7.1.3 Garbage and Recycling Receptacles

Fixed garbage and recycling receptacles must be provided at all Stations at locations that provide service access and meet the risk mitigation criteria identified in Appendix 10A.

The number of receptacles provided should be based on the Station layout and the projected Patron volumes and approved by the Operator. Garbage and recycling receptacles in accordance with ETS standards will be supplied by the Operator for placement at each Station entrance.

Garbage and recycling receptacles shielded from the wind are detailed in Figure 10.10 in Appendix 10B. The design for receptacles that are exposed to wind must be modified dependent on location.

10.7.2 Art

Artwork incorporated in public areas of LRT facilities must be provided as required by The City of Edmonton Art in Public Places Policy [9]. The Art in Public Places program is administered through the Edmonton Arts Council, which oversees the selection of the artist and artwork.

Once the selection of the artist and their art concept has been approved, the Designer and the artist must coordinate their activities to confirm that the criteria and restrictions for the placement of artwork meet the same codes, standards, and design criteria established for Stations and Ancillary Facilities.

10.7.3 Electrical & Communications Equipment

Electrical and communications devices on Platforms and in Stations provide Patrons with real time transit information and provide safety and security functions. All communications systems and equipment link the LRT OCC. Based on the type of Station, electrical systems may be distributed through a main electrical room or through marshalling cabinets.

Refer to Chapter 8, Communications for communications system requirements, function and design, and integration with other systems and facilities, such as TPSS and Signal System infrastructure.

Refer to Chapter 11, Electrical for electrical requirements.

Refer to Chapter 15, Safety and Security for CCTV coverage requirements.

10.7.3.1 Marshalling System Cabinet

Marshalling cabinets may be used in place of electrical and communications rooms in smaller Urban Style Stations. These cabinets provide an insulated housing for electrical and communications equipment in a compact form. The location and size of cabinets will vary depending on the architecture of the

Station, the Platform configuration, and individual Station equipment needs. Refer to Chapter 11, Electrical for details on Marshalling cabinets.

10.7.3.2 CCTV Cameras

All Stations must be equipped with a CCTV surveillance system that assists in the management of Train operations and provides public safety and security. CCTV camera details are provided in Chapter 15, Safety and Security and Chapter 8, Communications.

10.7.3.3 Public Address (PA) System

A PA system operates in conjunction with the Variable Message Sign (VMS) system to provide the capability for announcements to Patrons in all Stations. PA system details are provided in Chapter 8, Communications.

10.7.3.4 Variable Message Sign System

Variable Message Signs (VMS) are provided to augment the PA system with visual messaging. VMS system details are provided in Chapter 8, Communications.

10.7.3.5 Telephone Systems

The telephone systems to be installed in Stations and other Ancillary Facilities are classified as follows:

- ROW Phones
- Emergency Phones
- Elevator Phones
- Washroom Access Phones
- Information Phones
- Staff Service Phones

Autodialers (requiring a Telus phone line) must be coordinated with Chapter 8, Communications, Chapter 11, Electrical, and Chapter 12, Mechanical for equipment requirements.

Emergency, elevator, information, and washroom access phones are available for public use.

Refer to Chapter 8, Communications for detailed information on the placement and technical specifications for all telephone systems.

10.7.3.6 Open City Wi-Fi

All Stations must include free public Wi-Fi access to be coordinated with Open City Technology See Chapter 8, Communications for more information on public Wi-Fi.

10.7.3.7 Radio Systems

Refer to Chapter 8, Communications for information on radio system requirements and devices.

10.7.3.8 Information Panels

The integration of information panels into the Station design must be discussed early in the design process with Engineer and Operator.

10.7.3.9 Smart Fare Payment System Equipment

The ETS Smart Fare equipment supports an account-based electronic fare payment system that provides a range of progressive fare options, such as pay-as-you-go, fare capping, or distance-based fares. Use of the

Smart Fare payment system may eliminate the need to consider the Platform as a fare paid area. The Designer must confirm the approach to fare paid zones with the Engineer and Operator.

The Smart Fare Payment System includes SFVM and Smart Fare Validators (SFV). Fare equipment must conform to equipment selected for the regional Smart Fare system.

Patrons can make fare payments through the use of tap on and tap off functions at SFV, located along a Platform. A minimum of eight validators must be provided at each side-loaded Platform, evenly spaced along the boarding and alighting zone. Additional validators or double-sided validators may be required for centre loaded Platforms. Validators should be located close to Platform access points and must consider equipment service access, clearances and Patron circulation. The Designer must confirm final numbers and locations of SFV with the Engineer and Operator.

Each Platform must have a minimum of two SFVM, centrally located and spaced approximately 20 m to 40 m apart. Placement of SFVM must consider equipment service access, clearances, and pedestrian circulation, including Barrier-Free requirements. All operable controls must be between 380 mm and 1370 mm above the finished floor from a side reach parallel approach to the SFVM. Pushbuttons and other operable controls must be identified with high-contrast, raised lettering at least 16 mm high. No objects should protrude more than 100 mm from the finished floor to a height of 2030 mm on the front surface of the equipment. The minimum clear space wheelchair users require for a parallel approach to the SFVM is 760 x 1220 mm. The SFVM must provide audible voice instructions, upon request.

Final placement and quantities of SFVM and SFV will be determined based on Station characteristics and Platform type. SFVM must be sheltered from wind and rain. Fare equipment must be placed to avoid crowding and interference, while maintaining convenient Patron access to the equipment. Fare collection systems must be compatible with and support existing card payment systems already in use within the ETS system. The Smart Fare payment system must be readily accessible to persons with Disabilities and comply with the City of Edmonton Policy 602, Accessibility for People with Disabilities [54] and the City of Edmonton Access Design Guide [37].

10.7.3.10 Non-Fare Revenue Stream Equipment

Non-essential Platform equipment required as a revenue stream opportunity for the Owner should be determined on a Station specific basis in consultation with the Engineer and Operator. The technical provisions for all non-fare revenue generating equipment must meet the same standards for Accessibility, clearances, durability, maintenance and vandalism resistance as other Platform equipment. Refer to Chapter 11, Electrical for further information.

Non-fare revenue stream equipment may include the following:

Digital or Analog Advertising Panels

The provision and installation of advertising signage in or adjacent to Stations is generally the responsibility of a consultant under contract to the Operator. The Designer, in conjunction with the Operator, must determine possible locations for advertising panels. Once locations have been selected the Designer must specify anchorage and electrical service locations and requirements, including the concealment of power and data connections and adaptation of equipment mountings to the supporting structures and substrates of the Station.

Advertising panels must not conflict with or take priority over LRT System and Patron information or wayfinding signage including emergency exits or equipment. Panels must not obstruct CCTV coverage of the facility and must be compatible with the architectural theme of the Station. Advertising panels must be located and mounted such that installation and maintenance can be completed without shutting down the TP OCS. Panel locations and sizes will be determined by the Operator.

If lighting of advertising panels is deemed necessary, it should be identified as early as possible during Station design to allow coordination with the electrical design.

Vending Machines and Electronic Equipment

The Design must consider the required service connections for vending machines. Coordination and placement of all equipment must be reviewed with the Engineer and Operator.

Vending machines and electronic equipment may include the following:

Confectionary, Hot And Cold Drink Vending Machines

Vending machines may be located in main Station entrance areas but should be away from the entrance doors to reduce the potential for vandalism. Drink machines should be located next to confectionary machines. Both types of machines require individual electrical services. Hot drink machines require water services.

Paid Newspaper Boxes

Newspaper boxes should be located at the outside of the main Station entrances. Vehicle access for vendors should be provided in close proximity to box locations where practicable. Newspaper boxes must be securely anchored.

Free Newspaper Or Magazine Boxes

Free newspaper boxes should be located at main Station entranceways, although interior passageways may also be permitted.

Automated Teller Machines (ATM)

ATM should be located in the general vicinity of fare collection equipment. Electrical and data line service must be provided.

The Designer must review the feasibility of providing single use computer terminals at interior passageways away from congested areas. The need for these installations must be reviewed with the Engineer and Operator during design preparation.

10.8 SIGNAGE, BRANDING, AND WAYFINDING

The Operator has developed guidelines for designing, implementing, and maintaining information signage, graphic systems and branding elements within the LRT System. The guidelines allow the use of the Owner’s corporate identity and branding requirements in a consistent manner, provide consistency in the use and placement of visual elements, materials, finishes, colour, and typography, establish a functional and contemporary wayfinding system, and promote legibility and readability of pictograms and typographical elements.

10.8.1.1 Signage

Both static and electronic signage must be provided on Platforms and within Station areas.

Static signage includes wayfinding/exit signage and Station identification signage. On-Platform wayfinding and exit signage is used to direct Patrons to Platform exits identified by the adjacent cross streets. Wayfinding signage in the Station area or intersection node is used to identify neighbourhood connections, cross streets, transit connections, and local area destinations. Station identification signage must be provided on-Platform, both parallel to and facing the Trackway.

Digital signage includes the LRT System map and Train arrival VMS. The LRT System map and information panel must be provided on Platform and may incorporate interactive digital information or advertising. Digital Train arrival VMS must be located on-Platform to provide “next Train” information and may include other news or advertising.

The minimum distance from the top of the Platform to the underside of VMS, wayfinding, or exit signage system components must be 3000 mm and all components must be fitted with vandalism resistant housings and hardware. All VMS must be located to permit installation and maintainance with a 3050 mm long ladder.

Static regulatory signage provides direction to emergency phones, TVM, TVV, SFVM, and SFV, as well as Park and Ride lots. Restricted access, no trespassing, no smoking, and surveillance notification signage must also be provided.

All signage must conform to the LRT Graphics Standards, included in the ETS Brand Manual. Exterior wayfinding signage must comply with the guidelines and standards provided in Chapter 14, Urban Integration.

10.8.1.2 Branding

The objective of the ETS branding program is to enhance the Operator’s corporate identity by providing a consistent visual image. Primary visual branding is achieved using corporate colours in materials and finishes, ETS logo signage, and Station clock towers.

ETS Corporate Colours

The Designer must incorporate, where appropriate, the Operator’s corporate colours into the architectural features of each Station balanced with the overall architectural treatment of each Station. A primary design objective is to give each Station a unique appearance while at the same time being recognizable as an ETS facility.

ETS Logo

The Designer must locate large scale, high visibility “ETS” logo/brand signage on Station exterior walls. Locations must be adjacent to building entrance points, on large-scale walls or flat surfaces facing public approaches. Suitable locations must be determined jointly by the Designer and the Operator. Logo details will be provided by the Operator.

Lettering on buildings must be anodized, chrome plated, or powder coated metal pinned to the building surface with diffused halo Light Emitting Diode (LED) lighting placed behind the lettering. Sign transformers and electrical access must be concealed from view, located inside the building or soffit space. Maintenance access must be provided to all junction boxes or electrical low voltage driver locations.

10.8.1.3 Clock Tower

ETS clock towers are an important component of the Operator’s brand identity and must be a primary feature in LRT plaza areas, Transit Centre facilities, or Stations with larger multi-modal interchange functions. Clock towers may not be required at Urban Style Stations where there is a desire for greater neighbourhood integration and where there is limited available space.

If a Transit Centre is located adjacent to the Station, the clock tower must be located in the Transit Centre. The location of the clock tower must be determined in discussion with the Operator during design.

At all other locations where it is determined that a clock tower is required, the clock tower must be in a highly visible location for pedestrians and Patrons, as well as to adjacent Streets. Clock towers must be provided with a network connection for configuration and administration of all aspects of sign function. Electrical service must be provided from the Station electrical room.

The clock tower design must conform to the Operator's clock tower design and construction standard as shown on Appendix 10B Figure 10.8.

10.9 TRANSIT CENTRES

Refer to the Edmonton Transit Service Transit Center Guidelines for information on Transit Centre design.

10.10 UTILITY AND STAND-ALONE SERVICE BUILDINGS

Utility Complexes (UC) are typically located At-Grade near Stations and typically include Medium Voltage (MV) electrical, communications, and Signals infrastructure and mechanical facilities, together with a TPSS. Where Stations are located within a constrained ROW or are Urban Style Stations with a greater emphasis on SUI the Utility Complex may be designed and sized to accommodate the requirements for Station infrastructure as well.

A Utility Complex must be configured as a typical and expandable building form, able to accommodate additional program areas if required. Utility Complex buildings must include service access to one or two sides of the building allowing for efficient land use and exploiting proximity to adjacent to roads or plaza areas. A Utility Complex may also be designed to integrate with the adjacent neighbourhood context using complementary materials and design features or other urban design components or community amenities.

Depending on the type and configuration of a Station, some utility rooms may be required as a part of Platform or Station head design. Regardless of whether utility rooms are located within a Utility Complex, integrated into the Station Design, or are stand-alone Ancillary Facilities, the basic design requirements outlined below apply.

10.10.1 Traction Power Substation

10.10.1.1 Room Configuration and Building Requirements

TPSS rooms must be designed to accommodate MV transformers, switchgear, rectifiers, and other TPSS related equipment. Each TPSS room in a Utility Complex should be approximately 12 m x 12 m, while stand-alone TPSS should be approximately 12 m x 16 m. the interior height of the TPSS must be coordinated with the design of the traction power equipment. Minimum height requirements may be required for arc resistant switchgear that includes interior exhaust plenums. For stand-alone buildings, communications, building electrical equipment, and other services not related to the TPSS must not be located in the TPSS room.

The TP room must have two man-doors and one 3 m x 3 m equipment overhead door. Floors must be painted or sealed, and the floor must be level within +/- 1 mm over 1 m. The floor of the TPSS must be designed to support the weight of the TP transformer. All doors must have panic bar mechanisms and wall finishes must be designed to prevent dust buildup. Walls that support line and bypass switches must be designed to support the weight of the switches.

A desk and phone with autodialer system functions must be provided for maintenance and operations staff. A 15-minute self-contained, gravity-fed eyewash station and an accompanying first aid kit must be provided.

The Designer must coordinate the locations of both systems duct banks and grounding transition from outside the utility complex to the rooms within. For grounding, PVC conduits must pass through the building grade beam and foundation walls to allow ground conductors to pass from outside the building to locations inside the building.

Where a MV room is provided in a Utility Complex in lieu of an emergency generator room, the floor must be designed to support the weight of the transformer/generator and the floor must be designed to support the ducts and ground connections entering the building.

Fire detection systems and fire suppression systems must be provided unless stated otherwise by the Engineer. Refer to Chapter 11, Electrical and Chapter 12, Mechanical respectively for further information. When a TPSS is part of the same building as the Signals, communications, or data rooms, the required fire separation of the supporting structure of the TPSS must be a vertical fire separation that has a fire-resistance rating of not less than 2 hours.

Where a UPS/battery backup system has been included in the Design of the TPSS room, ventilation must be provided. Refer to Chapter 12, Mechanical for further information.

10.10.1.2 Service, Maintenance, and Utility Access Requirements

A 3.5 m x 3.5 m concrete pad on the exterior of the building must be installed in front of the equipment overhead door. A manhole must be installed outside each TPSS or UC building for access to the ROW TP duct banks. An additional, separate manhole must be provided outside of a Utility Complex for access to the ROW Signals and communications duct bank.

Maintenance vehicle access to manholes and the exterior concrete pad area must be provided. In addition, a minimum of two parking stalls must be provided at each TPSS or Utility Complex. Space must be allocated in the Utility Complex yard for EPCOR switch cubicles and a Station service transformer with appropriate clearance and access. Utility Complexes serviced with two separate EPCOR feeds may require two switch cubicles within the yard.

10.10.1.3 Mechanical Requirements

TPSS rooms must provide a Heating, Ventilating, Air Conditioning (HVAC) system to keep the ambient temperature within the operating range of the equipment and maintain positive pressure to reduce dust ingress. Dust ingress, especially dust fallout from a nearby Trackway, can damage electrical and communications equipment. Refer to Chapter 12, Mechanical for system requirements. HVAC equipment and ducts must be located to not interfere with the TPSS equipment. The HVAC system must be designed accounting for heat rejection of TPSS equipment. Refer to Chapter 12, Mechanical for ambient temperature requirements.

10.10.1.4 Electrical Requirements

Room lighting must be ceiling mounted LED fixtures which must be located to not interfere with TPSS equipment. Refer to Chapter 11, Electrical, for further information. Exterior light fixtures must be located near each man-door and battery powered emergency lighting to meet NBC (AE) must be provided. Refer to Chapter 6, Traction Power for more information.

Electrical outlets must be provided as per NBC-AE. Fire alarm devices such as smoke detectors and horn/strobes must be placed in accordance with CAN/ULC S-524 [201] and coordinated with the location of TPSS equipment. Final locations must consider ease of maintenance and testing.

10.10.1.5 Grounding

Refer to Chapter 6, Traction Power and Chapter 13, Corrosion and Stray Current for grounding details related to the Utility Complexes and TPSS.

10.11 UTILITY SERVICE ROOMS

As smaller Urban Style Stations are implemented along the LRT System, there is a greater emphasis on providing service rooms within larger stand-alone Utility Complex buildings. This approach acts to minimize the impact of large service rooms on the overall size of Station infrastructure by removing the need to house utility service rooms on Platforms or within Stations. The following guidelines outline the typical requirements for all utility service rooms.

Also refer to Appendix 10B for typical room sizes and equipment lists.

10.11.1.1 Finish Requirements

Epoxy flooring must be provided in all utility rooms. Wall finishes must be designed to prevent dust buildup and provide ease of maintenance. Refer to Section 10.11 for durability and maintenance considerations.

10.11.1.2 Electrical Requirements

Ceiling mounted LED linear fixtures must be located to not interfere with the room equipment. Utility rooms must be equipped with a dual technology ceiling mount and activated with a simple on/off switch. Battery powered emergency lighting must be provided to meet NBC-AE [13]. Fire alarm devices such as smoke detectors and horn/strobes must be placed in accordance with CAN/ULC S-524 [50] and coordinated with the location of equipment within the room. Final locations must consider ease of maintenance and testing. Refer to Chapter 11, Electrical for further details.

10.11.1.3 Communications & Security Requirements

Card access must be provided at all entry points to communication rooms. Card access or keyed access for outside service provider rooms must be reviewed with the Engineer and Operator. Refer to Chapter 8, Communications for further details.

10.11.1.4 Specific Requirements for Communications/Server/Data Rooms

Communication service rooms must be designed to accommodate CCTV and PA racks, telephone system backboards, BMS panels, corporate IT equipment, and other communications related equipment. Flooring must be anti-static and the room must be air conditioned. The Design must include a suspended cable tray system throughout the room.

Data rooms or server rooms may be required for some LRT projects. Specific requirements for each project are to be determined in consultation with the Engineer and the Operator. The ETS Data Centre Report will be provided by the Engineer if required.

A fire detection system and fire suppression system must be in all communications/server/data rooms unless stated otherwise by the Engineer. Refer to Chapter 11, Electrical and Chapter 12, Mechanical respectively for more information. Fire suppression systems may be contained in the communications/server/data room and must only deploy if a fire has started in, or has entered the room. Refer to the manufacturer's specifications for system requirements. Walls separating a communications/server/data room from other rooms or a corridor, must be a vertical fire separation that has a fire-resistance rating of not less than 2 hours.

The mechanical system must be designed to limit dust ingress. Refer to Chapter 12, Mechanical for system requirements. The Designer must confirm all equipment ventilation requirements with the Engineer and the Operator.

10.11.1.5 Specific Requirements for Signals Rooms

Signals rooms should be approximately 6 m x 7 m (42 m^2) and must be designed to house Signal relay and Signal power equipment. The room must be air conditioned. The Designer must confirm other ventilation requirements with the Engineer and the Operator. A fire suppression system must be provided in Signals rooms unless stated otherwise by the Engineer, and must only deploy if a fire has started in, or has entered, a Signals room. Refer to Chapter 12, Mechanical for more information. Signal rooms must include UPS/battery bank back-up. Refer to Chapter 8 Communications, and Chapter 12 Mechanical for further information. Walls separating a Signals room from other rooms or a corridor must be a vertical fire separation that has a fire-resistance rating of not less than 2 hours.

10.11.1.6 Specific Requirements for Mechanical Rooms

Mechanical service rooms must be designed to accommodate pumps, fans, motors, and other required equipment as dictated by the design of Station or other Ancillary Facilities. Refer to Chapter 12, Mechanical for design and equipment requirements.

10.11.1.7 Specific Requirements for Electrical Rooms

Electrical rooms must be approximately 10 m x 5 m (50 m^2). For smaller Urban Style Stations, on-Platform electrical rooms are generally not feasible. Instead, Power Distribution Centers (PDC) near Stations may be used to provide the power feeds to marshalling cabinets on Platforms. Refer to Chapter 11, Electrical for additional information.

Where a marshalling cabinet is not sufficient to provide the electrical requirements for a particular Station, an electrical room may be required. Refer to Chapter 8, Communications and Chapter 11, Electrical for further information.

10.11.1.8 Specific Requirements for UPS Electrical Rooms

The Uninterruptable Power Supply (UPS) for a facility must be located within a separate electrical room. Refer to Chapter 8, Communications, Chapter 11, Electrical, and Chapter 12, Mechanical for further information.

10.12 PARK AND RIDE FACILITIES

The City of Edmonton Park and Ride Guidelines [41] outline the policies and strategies for the implementation of Park and Ride facilities and the relationship to TOD initiatives. Park and Ride facilities may be provided at selected Stations as determined through the planning process. All usage projections and required soft capacities for parking facilities must be obtained from the Engineer. Special circumstances such as site constraints, joint-use partnerships, Street level design interface, or other requirements for wrap-around commercial uses, may determine that a parking structure is required.

This section presents supplementary information for the design of Park and Ride facilities specific to the LRT System and must be read in conjunction with the City of Edmonton's Park and Ride Policy [24] and Guidelines [41].

10.12.1 Access & Circulation

Parking spaces and traffic aisles must be designed to allow for easy maneuverability of vehicles. The type of circulation system for the design vehicle dimensions and loads must be evaluated by the Designer in consultation with the Engineer. The design vehicle may include standard passenger vehicles, emergency vehicles, and snow removal or maintenance equipment.

The number of pedestrian crossings between the Park and Ride lot and the Station or an adjoining bus transit facility should be minimized. Pedestrian crossings must be designed to safely collect and move pedestrians at dedicated crossings and discourage or eliminate random crossing points. For At-Grade facilities, the Designer should consider pedestrian collector elements or pedestrian-only walkways so that drive aisles do not become the primary means of pedestrian access to the Platforms. If warranted by high anticipated pedestrian and vehicle volumes, pedestrian activated flashers and dedicated lighting of pedestrian crossings may be required.

Obstructions to sight lines at entrances and exits to Park and Ride lots must be minimized. All pedestrian walkways and egress/access points must be well illuminated, highly visible, and located to provide safe and accessible pedestrian movements that are protected from motor vehicles and otherwise designed in alignment with CPTED principles [47]. Refer to Chapter 14, Urban Integration for additional multi-modal interchange design requirements.

Travel distance for pedestrians along drive aisles and pedestrian walkways should be minimized. When pedestrian flow cannot be oriented parallel to the aisles or when aisle lengths exceed 122 m in length, separate pedestrian sidewalks perpendicular to the aisles should be considered. These pedestrian sidewalks must be clearly marked and meet the requirements of the current City of Edmonton Design and Construction Standards (D&CS) [202].

Some fencing types can act as a barrier to the integration of a parking facility with adjacent neighbourhoods and can negatively impact walk-up ridership. The Designer must confirm fencing requirements in consultation with the Engineer.

10.12.1.1 Stall and Aisle Layout and Configuration

Parking lot stall and aisle dimensions must meet the minimum requirements described in the NBC-AE, the City's Access Design Guidelines [195], and City of Edmonton Bylaw 12800 [179].

Service Vehicle stalls may be designed as a standard vehicle stall. Parking must be provided by straight parking stalls for areas where there is two-way traffic flow and by angled parking stalls for areas where there is one-way traffic flow.

Drive aisles should be aligned for convenient pedestrian movement toward a Station or transit facility. Dead end aisles should not be used.

10.13 PARKING

10.13.1.1 Curbs and Medians for Surface Parking Lots

Curbs must be provided around the entire perimeter of a parking area, circulation roadways, at raised concrete medians, and other locations as defined by the Engineer. Curb design must be in accordance with City Design and Construction Standards, Volume 2, Roadways [51].

10.13.1.2 Landscaping

The total area required for landscaping and screening of parking lots must meet the requirements of the City Zoning Bylaw 12800 [179]. The landscaping design must be done in accordance with the principles stated in Chapter 14, Urban Integration and City Design and Construction Standards, Volume 5, Landscaping [51].

10.13.1.3 Safety & Security

Security of Patrons in parking facilities is of paramount importance. The Designer must refer to Chapter 15, Safety and Security and the Edmonton Zoning Bylaw 12800 [17] for safety and security requirements.

10.13.1.4 Signage

All parking lot signage must be designed in accordance with the LRT Graphic Standards Manual. All markings and graphics must be clearly visible, simple, free from clutter, and easily read.

Exterior Park and Ride identification signs must be visible to motorists on adjacent Streets. Each parking lot entrance must include customer information signage displaying operational hours.

Signs that are critical to the operation of the parking lot must be illuminated during night-time hours.

Signs must be Ultra-Violet (UV) resistant and non-corroding.

10.13.1.5 Graphics, Painting, and Pavement Markings

Floor levels, stairwells, and elevator lobbies must be clearly labeled using numbers, color codes, and/or symbols.

All Barrier-Free Accessible stalls must be labelled as defined in the NBC-AE and the Alberta Barrier-Free Design Guide.

10.14 MATERIALS AND FINISHES

The selection of materials and finishes for LRT Stations and Ancillary Facilities must consider the combined impacts of local climate, current ETS maintenance practices and procedures, and heavy daily use by ETS Patrons and the public. The quality and character of materials and final finishes selected, combined with an understanding of the associated service environment will directly affect the appearance and predicted service life of each facility.

At minimum, Designers must meet the requirements of the City's Facility Design and Construction Consultant Manual, Volume 1, Design Process and Guidelines [41]; and Volume 2 Technical Guidelines [42].

10.14.1 Quality Objectives

The chosen materials and finishes should maximize aesthetic quality in conjunction with Patron safety and comfort. Durable materials and components in robust assemblies with reliable supply chains enhance the character and visual quality of each Station while promoting the ETS brand.

10.14.2 Maintenance Objectives

10.14.2.1 Minimize Life Cycle Costs

The Designer must specify materials and systems that consider maintenance, repair, and replacement schedules. Standardized materials, components, and assemblies optimize scheduling of regular maintenance and facilitate rapid repair or replacement and minimize O&M costs.

10.14.2.2 Optimize Procurement and Construction

The Design should prioritize the use of readily available materials and finishes with dependable, long-term local and regional supply chains, procured through competitive bidding. The Design goal is to create robust, integrated assemblies where the least durable or obsolescence-prone materials or components are readily accessed and replaced with minimal or no deconstruction or demolition.

10.14.2.3 Design for Maintainability and Replacement

All materials and finishes should be durable and non-toxic and require less frequent maintenance using less potable water, less energy, and non-toxic cleaning agents. The Design should reduce or eliminate the need for hazardous maintenance, repair, or replacement materials and procedures.

The Designer should reduce or eliminate the need for specialized infrastructure or procedures for the safe and efficient handling, disposal, re-use, or recycling of maintenance residuals during or at the end of service, and allow for simple and effective repair of incidental damage or casual vandalism.

The Design must avoid details with unnecessary joints or surfaces that attract or collect soil or that complicate cleaning or repairs.

Any elements of Stations, UC, or other facilities associated with the LRT system that require regular service or maintenance and are located at height, must be serviceable with a ladder no higher than 3050 mm.

10.14.3 Performance Standards

10.14.3.1 Durability

The Designer must refer to CSA S478-95 Guideline on Durability in Buildings [188], and should use inherently durable materials with non-toxic constituents that, where possible and appropriate, include significant recycled content or that are easily recycled or repurposed. Materials should have physical properties consistent with their predicted service life within the varied and typical service environments found throughout LRT facilities.

Materials exposed to the elements should have consistent weathering properties and be compatible with the Edmonton climate. Exposed base building materials or substrates should be capable of maintaining internal material and external visual integrity throughout their service life with minimal maintenance. Corrosion-resistant metals or metals with maintenance-free corrosion-resistant finishes, should be used to reduce or eliminate the combined effects of water, de-icing agents, and electrical current typical of LRT operations.

Combinations of dissimilar or highly reactive materials and metals used in close proximity or in composite assemblies exposed to corrosive or oxidizing conditions must be isolated, galvanically or otherwise, as required. See Chapter 13, Corrosion and Stray Current for more information.

Building materials and finishes that are within reach of Patrons (i.e. less than 2700 mm above finished floor level) should be selected and applied to prevent or diminish the impacts of normal wear and tear and willful vandalism.

Building materials and finishes used in assemblies or areas frequently exposed to water (i.e. rain, condensation, ice, and snow) must be selected and detailed with proper attention to drying, deflection, drainage, and durability. Materials and finishes used should, with few exceptions, be dense, hard, and nonporous. Materials and finishes should, to the greatest degree possible, impart or have built-in corrosion, acid, and alkali resistance.

Graffiti proofing products should be used to protect surfaces susceptible to graffiti, and specialty coatings and finishes should be considered for public areas, if not tiled.

10.14.3.2 Energy and Material Efficiency

The Design should use materials that, from the point of resource extraction through to decommissioning, have the lowest embodied energy and that are inherently energy efficient. Material selection should, wherever possible, support more than a single purpose, effect, or function.

10.14.3.3 Appearance

Materials and finishes for Stations and Ancillary Facilities should harmonize with or be shared among similar facilities within the LRT System. On a site-specific basis due to heritage considerations or other community imperatives, materials and finishes may have to harmonize with existing facilities in the vicinity of the Station.

Non-pigmented, bond-breaking anti-graffiti coatings and treatments that are applied to surfaces susceptible to graffiti should be selected to minimize impacts on the appearance (i.e. sheen, texture, colour) of the receiving substrate as well as the frequency and difficulty of removing graffiti or to later application of other protective or decorative coatings.

Material colour, texture, pattern, and light-reflecting or light absorbing properties should be considered specifically or understood generally for impacts on Patron safety related to how these properties are heightened or diminished under a range of light sources throughout the day and night and across the seasons.

10.14.3.4 Acoustic

The acoustic aspects of material selection and location have direct and measurable impacts on the safe and enjoyable use of LRT facilities.

Material design must consider the acoustic performance and function related to either heightening or diminishing sound intensity through reflection, absorption, vibration, or reverberance to improve speech intelligibility, provide audible feedback to the visually impaired, or limit sound trespass into adjacent spaces, buildings, and land uses.

10.14.3.5 Tactile

The Designer should choose materials required for grasping by hand or as seating surfaces that are ergonomically optimized and safe with respect to texture, sharp edges, cleanliness, and heat conduction.

Material substrates and mounting conditions for TWSI that offer significant and easily detectable levels of tactile contrast between the TWSI component and the surrounding walking surfaces that are slip-resistant must be provided.

Walking surface materials and finishes that have or impart slip-resistance levels that are appropriate for the service environment and anticipated foot traffic levels, exposure to the elements, temperature range, and frequency and type of maintenance must be provided.

All concrete walking surfaces and other floor finishes, including Station access ramps, Platform surfaces and stairs treads must have a high slip resistance rating, meeting a dry static coefficient of friction of 0.5 or greater as per ASTM D2047 Static Coefficient of Friction [203]; and a wet dynamic coefficient of friction of 0.43 as per ANSI/NFSI B101.3-2012, Test Method for Measuring Wet DCOF of Common Hard-Surface Floor Materials [192].

APPENDIX 10A – RISK ASSESSMENT CRITERIA FOR PLACEMENT OF GARBAGE/RECYCLING RECEPTACLES

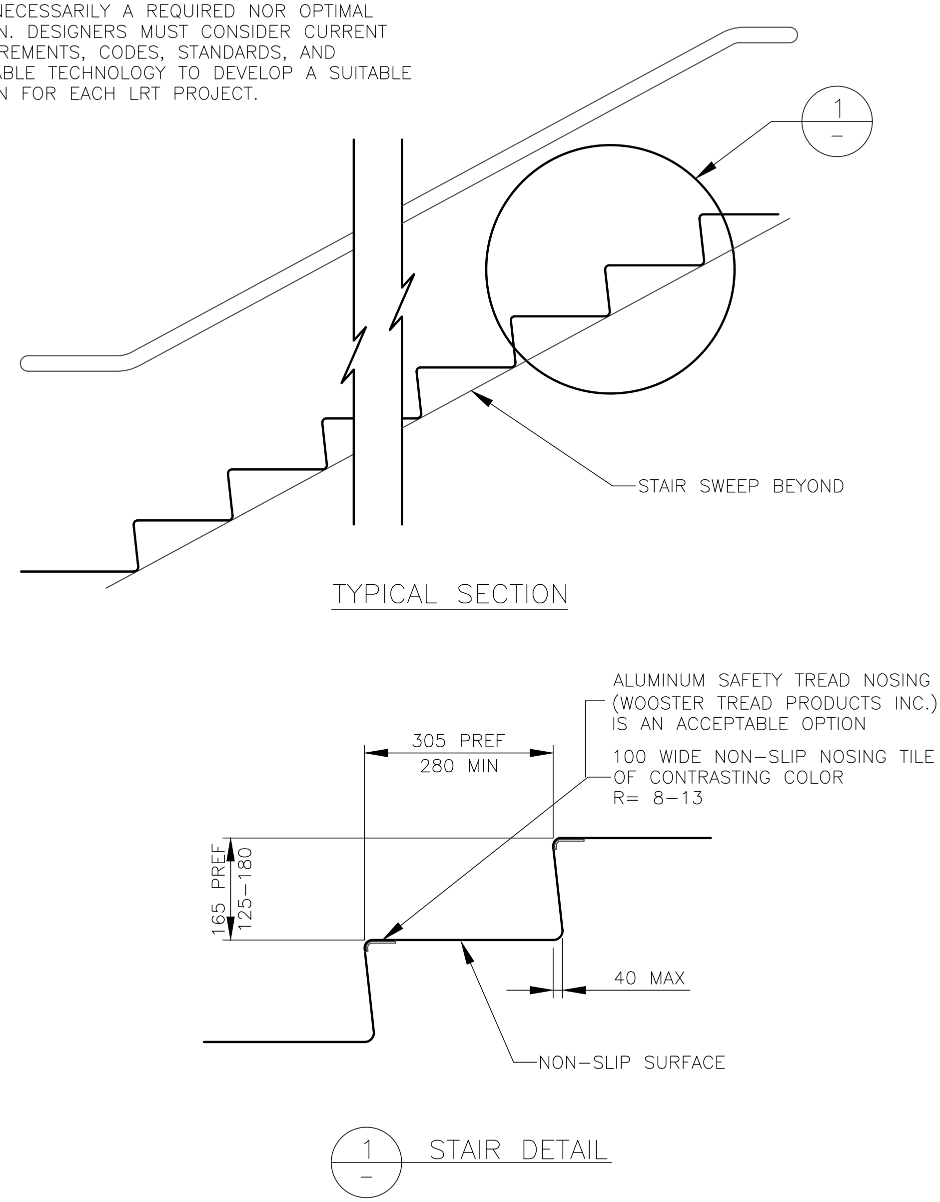
APTA Category	Description	Risk Element	Low Risk Element	Comments
Pedestrian access and egress points to/from Stations			**X**	See Note 1
Areas where people congregate	Platform level		**X**	See Note 1
Pedestrian bottlenecks	Stairways/escalators		**X**	See Note 1
	Elevators		**X**	See Note 1
Location of critical structural elements in underground Stations	Columns	**X**		Major impact of structural failure
	Load bearing walls	**X**		Major impact of structural failure
Location of critical structural elements in surface Stations	Columns		X	Reduced impact of structural failure
	Load bearing walls		X	Reduced impact of structural failure
Walkways	Hallways		X	See Note 1
	Open walking areas		X	See Note 1
Glass	Glass enclosures	X		Produces significant amounts of shrapnel
	Small glass barriers		X	Produces limited amounts of shrapnel
Enclosed spaces	Alcoves/vestibules	X		Receptacle not visible to pedestrians; poor blast dispersion
Ceiling height			X	See Note 1
Utilities	HVAC		X	Limited potential for secondary effects
	Smoke fans	X		Critical to evacuating smoke
	Electrical		X	Limited potential for secondary effects
	Communications	X		Incident reporting/emergency response
	Gas mains	X		Impact of secondary explosion is major
	Gas connections		X	Impact of secondary explosion is less
	Fire-life safety systems		X	Limited potential for secondary effects
	High pressure steam	X		Potential for secondary effects
	Signal room/substation	X		Required to maintain power/Train control
Flammable and toxic materials			X	Minimal storage of materials in LRT Stations

Note 1: In general, Edmonton's LRT System is currently at a low risk level to the threat of an explosive event. The risk is mitigated by the use of clear plastic receptacles placed in high visibility areas.

APPENDIX 10B – FIGURES

CITY OF EDMONTON
LRT DESIGN GUIDELINES

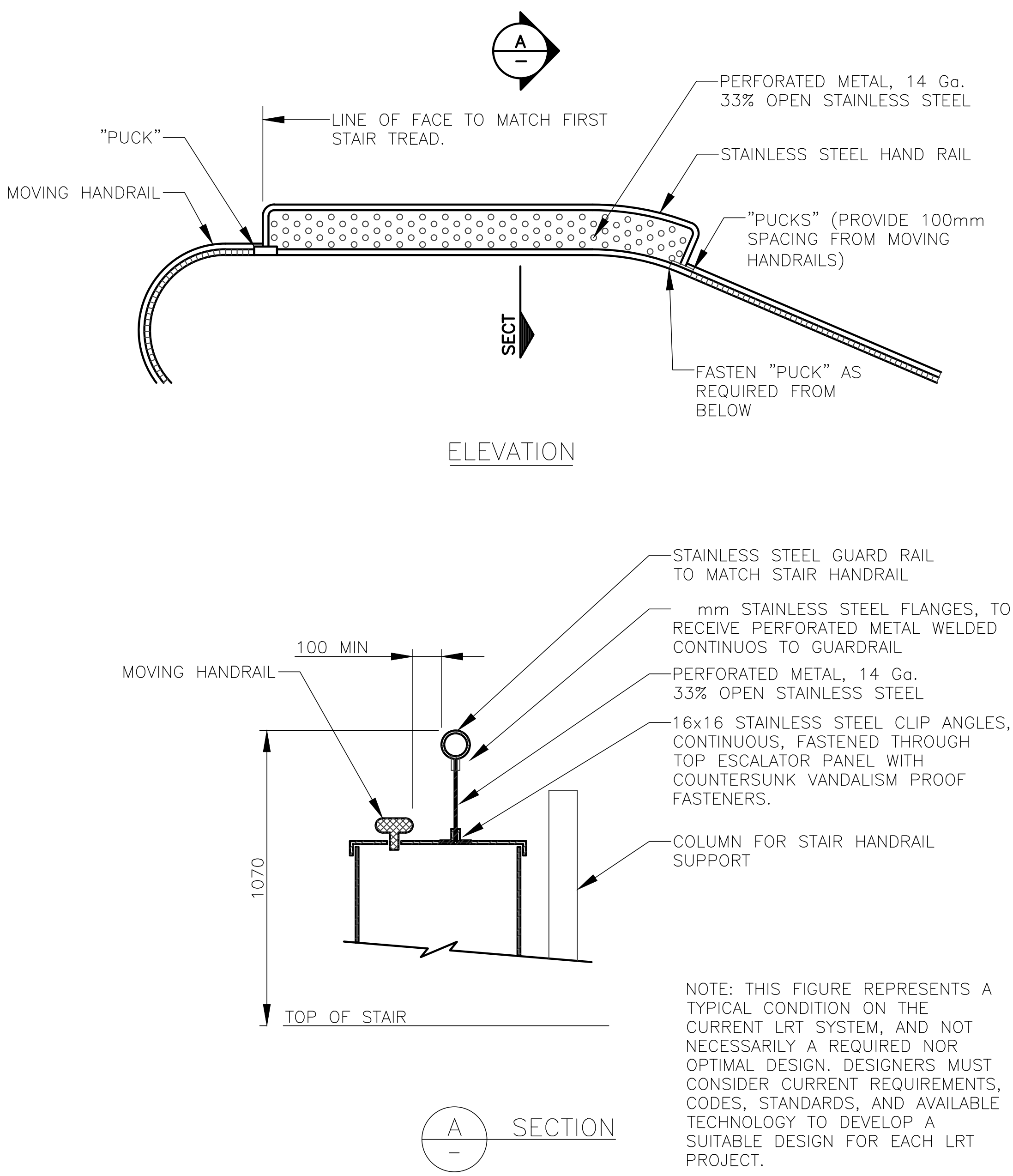
NOTE: THIS FIGURE REPRESENTS A TYPICAL CONDITION ON THE CURRENT LRT SYSTEM, AND NOT NECESSARILY A REQUIRED NOR OPTIMAL DESIGN. DESIGNERS MUST CONSIDER CURRENT REQUIREMENTS, CODES, STANDARDS, AND AVAILABLE TECHNOLOGY TO DEVELOP A SUITABLE DESIGN FOR EACH LRT PROJECT.



ALL DIMENSIONS IN mm.

		FIGURE 10.1 STAIR DETAIL	CHAPTER 10
			STATIONS AND
			ANCILLARY FACILITIES
DD-MM-YY	REV1		
Date	Description		

CITY OF EDMONTON
LRT DESIGN GUIDELINES



NOTE: THIS FIGURE REPRESENTS A TYPICAL CONDITION ON THE CURRENT LRT SYSTEM, AND NOT NECESSARILY A REQUIRED NOR OPTIMAL DESIGN. DESIGNERS MUST CONSIDER CURRENT REQUIREMENTS, CODES, STANDARDS, AND AVAILABLE TECHNOLOGY TO DEVELOP A SUITABLE DESIGN FOR EACH LRT PROJECT.

		FIGURE 10.2 ESCALATOR GUARD	CHAPTER 10
			STATIONS AND
			ANCILLARY FACILITIES
DD-MM-YY	REV1		
Date	Description		

CITY OF EDMONTON
LRT DESIGN GUIDELINES

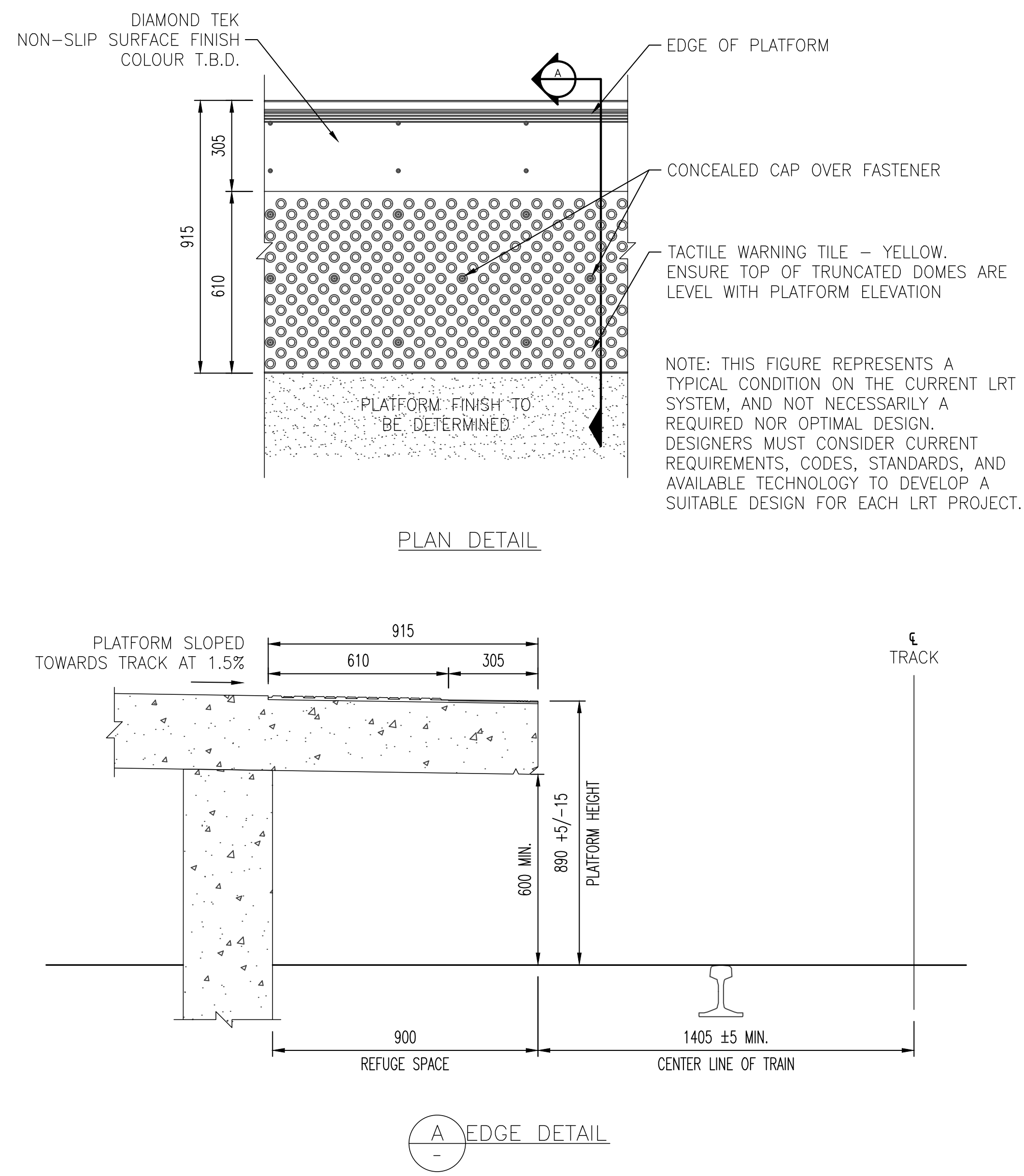


		FIGURE 10.3	CHAPTER 10
		PLATFORM TACTILE WARNING STRIP	STATIONS AND
			ANCILLARY FACILITIES
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Date	Description		

CITY OF EDMONTON
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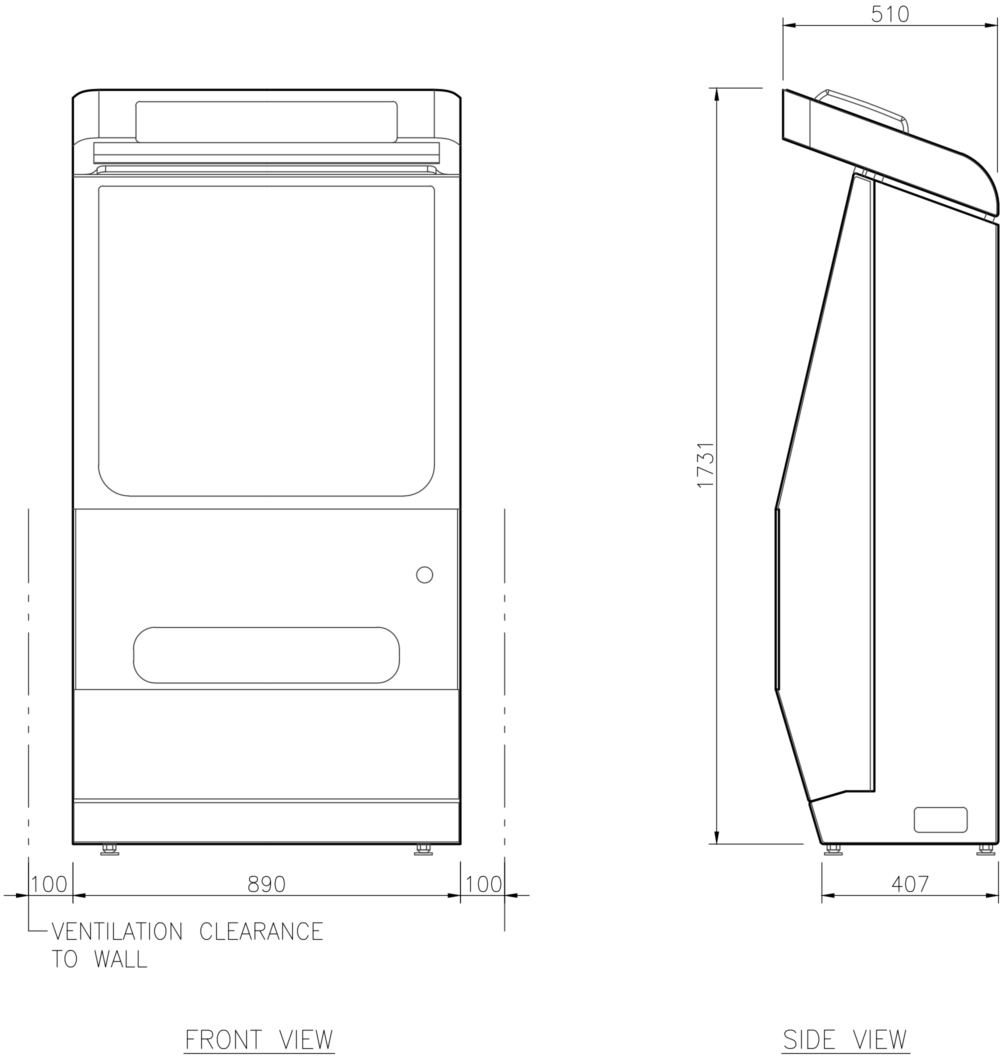

		FIGURE 10.4	CHAPTER 10
		TICKET VENDING MACHINE	STATIONS AND
			ANCILLARY FACILITIES
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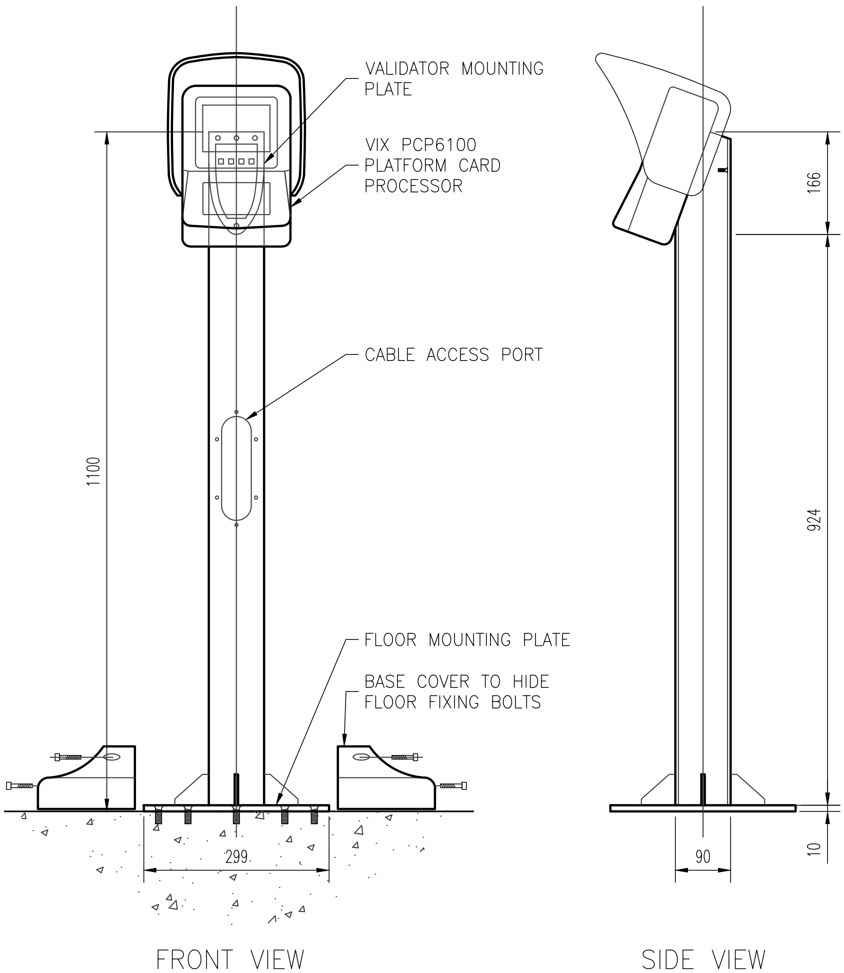
Date	Description		

CITY OF EDMONTON
LRT DESIGN GUIDELINES



NOTES:

- VALIDATOR STAND MATERIAL BRUSHED STAINLESS STEEL
- VALIDATOR TO BE SHROUDED IF LOCATED IN AN UNCOVERED PORTION OF THE PLATFORM
- THIS FIGURE REPRESENTS A TYPICAL CONDITION ON THE CURRENT LRT SYSTEM, AND NOT NECESSARILY A REQUIRED NOR OPTIMAL DESIGN. DESIGNERS MUST CONSIDER CURRENT REQUIREMENTS, CODES, STANDARDS, AND AVAILABLE TECHNOLOGY TO DEVELOP A SUITABLE DESIGN FOR EACH LRT PROJECT.

		FIGURE 10.5	CHAPTER 10
		FARE VALIDATOR STAND	STATIONS AND
			ANCILLARY FACILITIES
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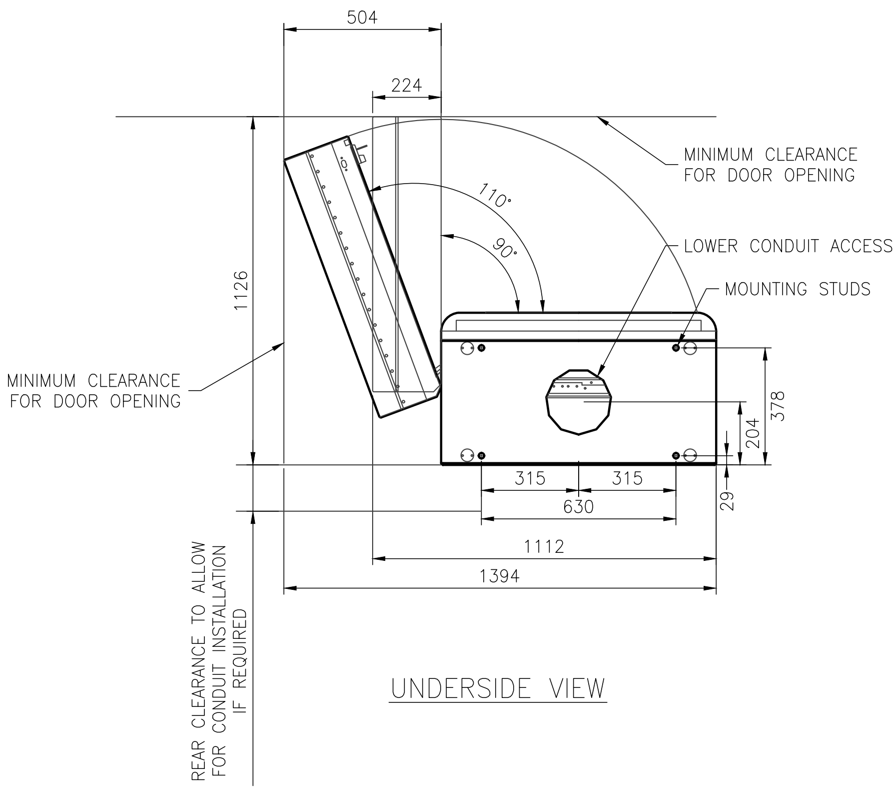
CITY OF EDMONTON
LRT DESIGN GUIDELINES



NOTE: THIS FIGURE REPRESENTS A TYPICAL CONDITION ON THE CURRENT LRT SYSTEM, AND NOT NECESSARILY A REQUIRED NOR OPTIMAL DESIGN. DESIGNERS MUST CONSIDER CURRENT REQUIREMENTS, CODES, STANDARDS, AND AVAILABLE TECHNOLOGY TO DEVELOP A SUITABLE DESIGN FOR EACH LRT PROJECT.

		FIGURE 10.6	CHAPTER 10
		TICKET VENDING MACHINE ANCHORING DETAIL	STATIONS AND
			ANCILLARY FACILITIES
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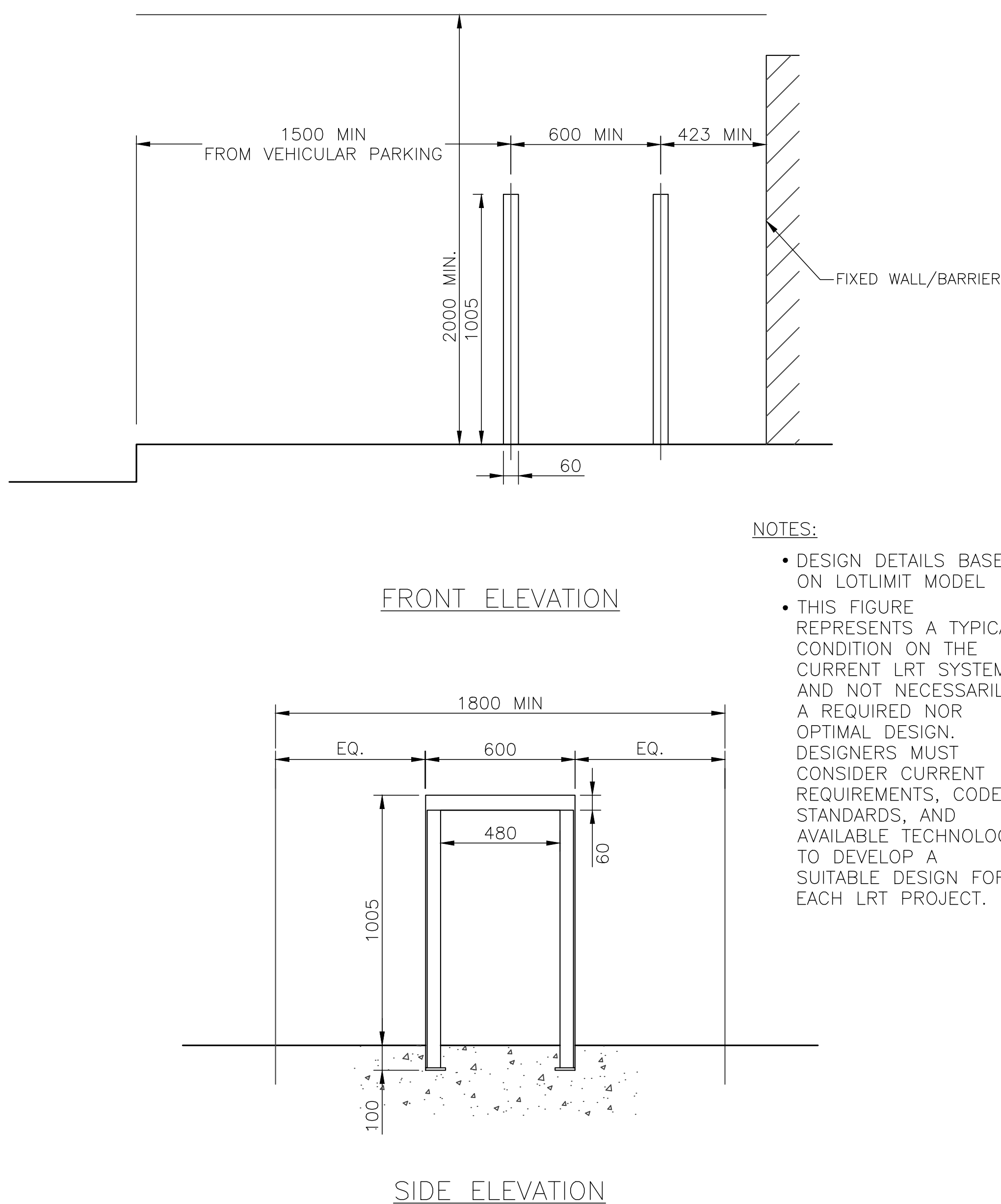
CITY OF EDMONTON
LRT DESIGN GUIDELINES



NOTES:

- DESIGN DETAILS BASED ON LOTLIMIT MODEL
- THIS FIGURE REPRESENTS A TYPICAL CONDITION ON THE CURRENT LRT SYSTEM, AND NOT NECESSARILY A REQUIRED NOR OPTIMAL DESIGN. DESIGNERS MUST CONSIDER CURRENT REQUIREMENTS, CODES, STANDARDS, AND AVAILABLE TECHNOLOGY TO DEVELOP A SUITABLE DESIGN FOR EACH LRT PROJECT.

		FIGURE 10.7	CHAPTER 10
		BIKE STAND	STATIONS AND
			ANCILLARY FACILITIES
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Date	Description		

CITY OF EDMONTON
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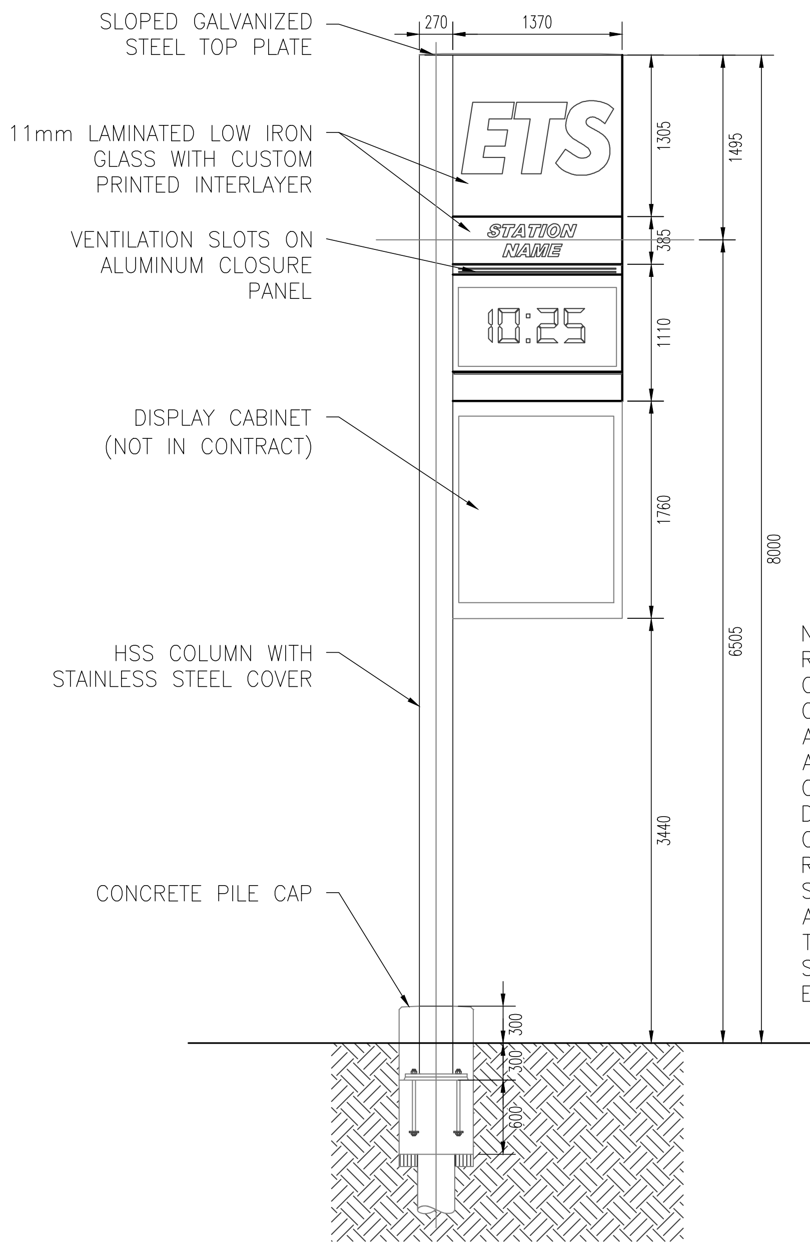

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		FIGURE 10.8	CHAPTER 10
		TYPICAL STATION CLOCK TOWER	STATIONS AND
			ANCILLARY FACILITIES
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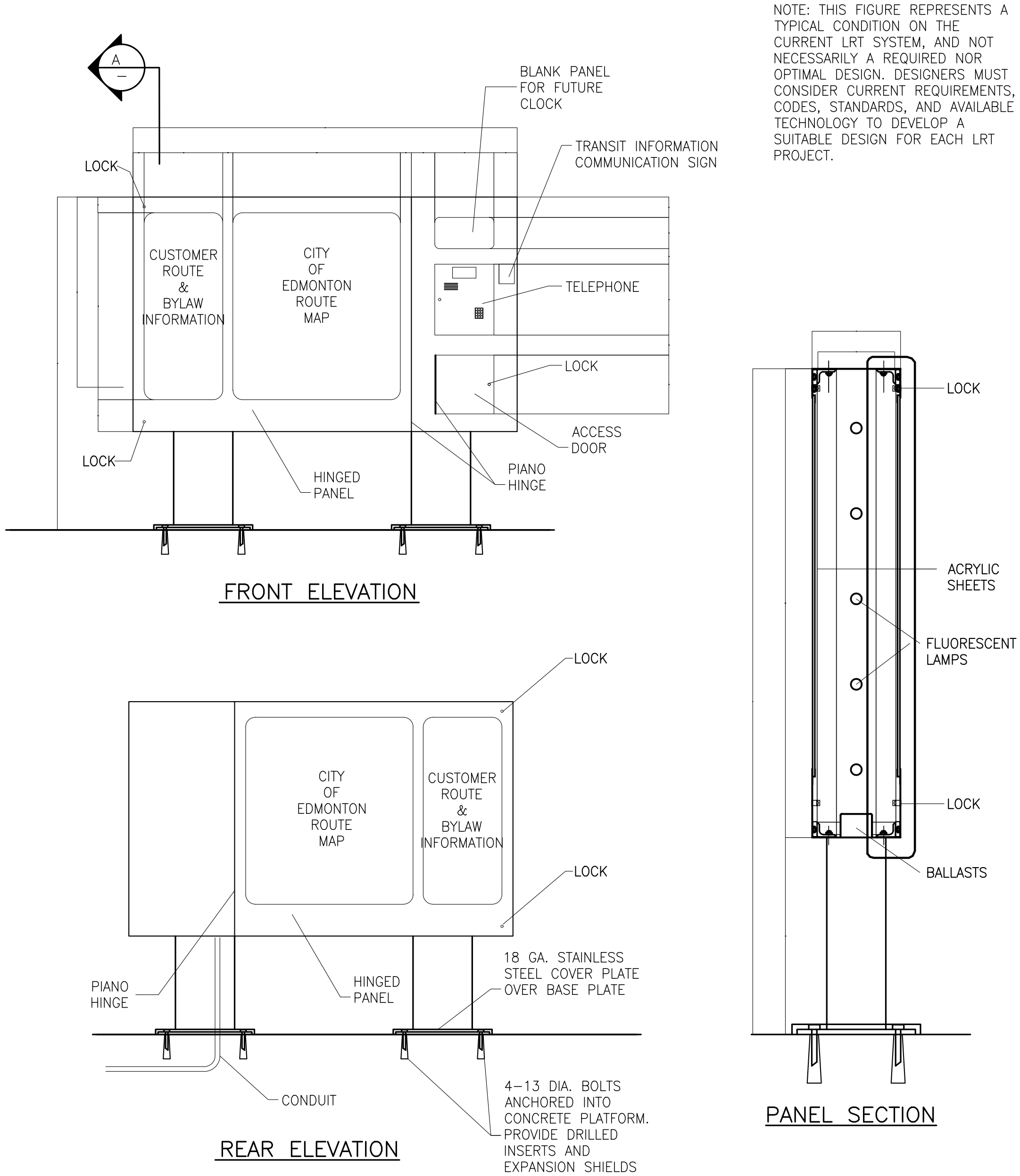

		FIGURE 10.9	CHAPTER 10
		TYPICAL INFORMATION PANEL LAYOUT	STATIONS AND
			ANCILLARY FACILITIES
DD-MM-YY	REV1		
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CITY OF EDMONTON
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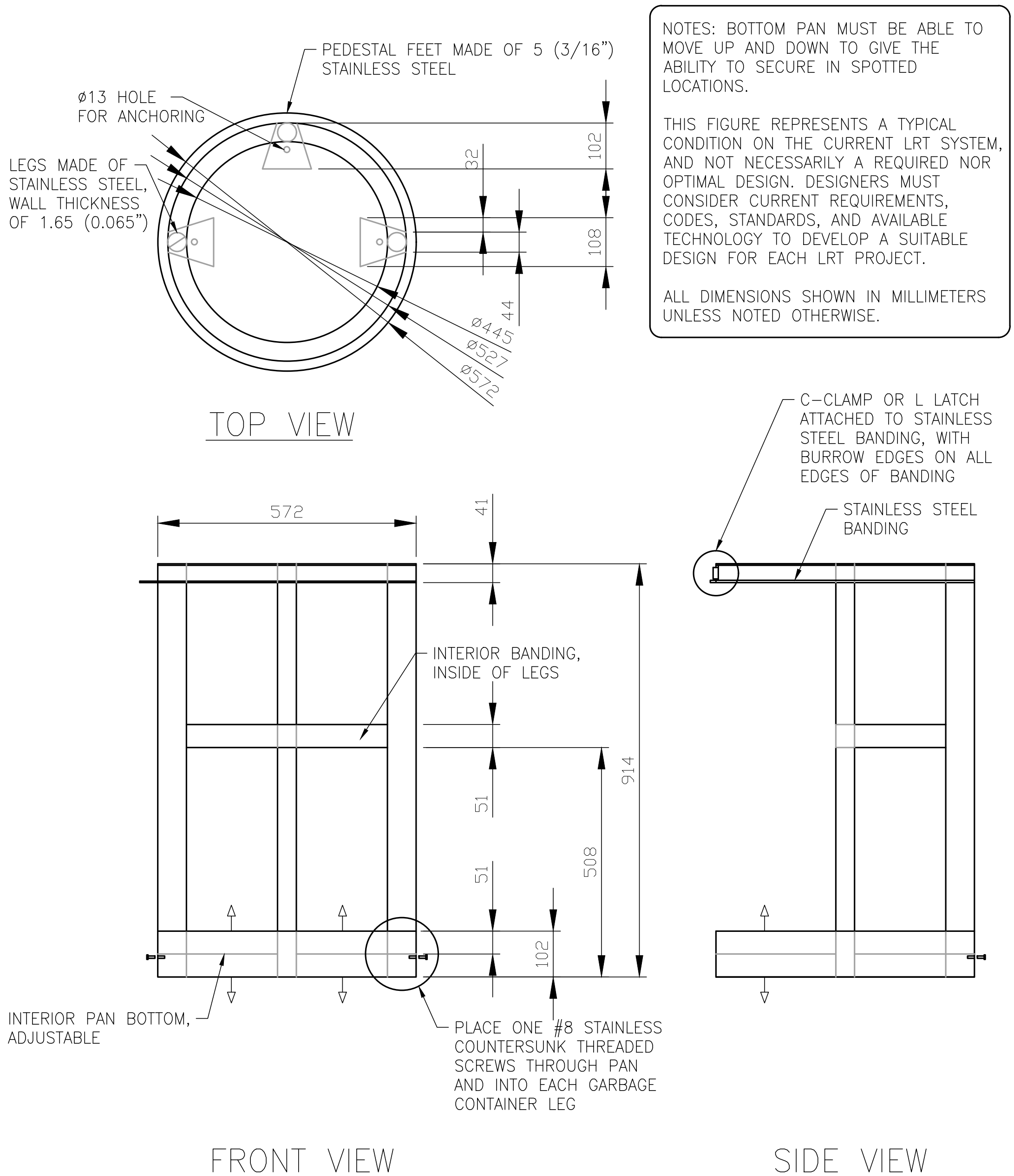

		FIGURE 10.10	CHAPTER 10
		GARBAGE RECEPTACLE	STATIONS AND
			ANCILLARY FACILITIES
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CHAPTER 11

Electrical

COE-IM-GUIDE-0017 | v02

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INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

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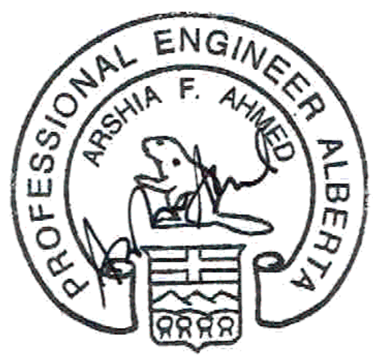

March 29, 2022
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11 ELECTRICAL

11.1 INTRODUCTION

This chapter provides electrical system design guidelines for the LRT System. The electrical system includes power services to:

- Stations
- Tunnels and portals
- Bridges and structures
- LRT Right-of-Way (ROW) systems and services
- UC
- Traction Power Substations (TPSS)
- Maintenance facilities
- Parking facilities

This chapter also includes guidelines for:

- Power Distribution Equipment
- Lighting and Lighting Control System
- Fire alarm and detection
- Grounding and bonding
- Lightning Protection System
- Duct banks and raceways
- Utility coordination

This chapter includes the duct bank, raceway, grounding, and bonding requirements for the Traction Power (TP) systems but excludes the TP electrical and mechanical components that are discussed in Chapter 6, Traction Power.

11.1.1 Applicable Codes, Standards, and Regulations

Unless stated otherwise, the Design must conform to or exceed the requirements of the latest editions of all applicable Federal, Provincial, and Municipal codes and regulations.

Codes, regulations and standards are issued by the following bodies:

- American National Standards Institution (ANSI)
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
- American Society for Testing and Materials (ASTM)
- Canadian Standards Association (CSA)
- Canadian Electrical Manufacturers Association (CEMA)
- Canadian Government Specifications Board (CGSB)
- Electro Federation of Canada (EFC)
- Electrical Equipment Manufacturers Advisory Council (EEMAC)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Society for Measurement and Control (ISA)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)

- Underwriters Laboratories of Canada (ULC)

The following specific documents are to be used for Design:

- National Building Code – Alberta Edition [152]
- National Energy Code of Canada for Buildings (NECB)
- Alberta Electrical and Communication Utility Code (AECUC)
- Alberta Electrical Code Regulation (AECR) [204]
- Alberta Safety Code Act (ASCA) [4]
- Canadian Electrical Code (CEC) [42]
- Lighting Handbook (IES) [205]
- National Building Code of Canada (NBC) [2]
- Occupational Health and Safety Act (OHSA) [82]

Reference guidelines for the Design include:

- Facility Design & Construction Consultant Manual Volume 1 & 2
- City of Edmonton Design Guide for a Safer City [206]
- EPCOR Customer Connection Guide [45]
- Going Places – Accessibility Needs of Visually Impaired Travelers in Transportation Facilities, CNIB 1997
- LEED Green Building Rating System [207]
- NFPA 130 Standard for Passenger Rail Systems [17]
- NFPA 70 National Electrical Code [208]
- Road and Walkway Lighting Manual [209]
- TCRP Report on Passenger Loading
- Transportation Services Electrical Services Plan (TESP)
- Installation Code for Lightning Protection Systems (CSA B72)

11.2 ELECTRICAL SYSTEM DESCRIPTION & REQUIREMENTS

The LRT electrical system receives Alternating Current (AC) power from a utility provider and distributes normal, essential, and critical power to the various facilities and systems servicing the LRT. Depending on the area of the city, 15 or 25 kV_{AC} three phase utility power is typically stepped down to 600 V_{AC} for distribution by the LRT electrical system. At the load location, the power is further stepped down to 120/208 V_{AC} or 240 V_{AC} for use by the end devices.

The LRT right-of-way (ROW) power is distributed to end devices and equipment. The type of power provided depends on the requirements in the area. Where multiple systems are required, the Design should provide a joint use Utility Complex (UC) placed near the associated Station. The UC houses the electrical room that services the communications, Signals, TP, Medium Voltage (MV), and mechanical rooms in the building. A typical UC equipment layout is shown in Appendix 11A, Figure 11.1. The electrical room must service the nearby Station and the ROW electrical distribution system through distributed power infrastructure.

For Operations and Maintenance Facilities (OMF) or below-grade Stations, electrical rooms must be incorporated into the OMF building or below-grade structure. For Urban Style At-Grade stations, dedicated electrical rooms should be replaced by marshalling cabinets near the stations.

11.2.1 Electrical Loads

11.2.1.1 Normal Power (Utility)

Normal power is supplied from the utility provider to downstream systems with typically no redundant power from an alternate source. The loads connected to normal power are those that can tolerate the occasional prolonged interruption. Equipment connected to normal power includes, but is not limited to:

- Non-emergency lighting
- Advertising signage
- Non-essential space heaters
- Non-essential ventilation systems
- Non-essential pumps and fans
- Maintenance receptacles
- Heating Ventilation Air Conditioning (HVAC) systems - when room overheating conditions cannot cause system failures
- Heat tracing
- Vacuum systems
- Vending equipment

11.2.1.2 Essential Power (Utility and Standby)

Essential power is normal power backed up by a standby source such as an alternate utility feed or an on-site permanent or portable generator. The loads connected to essential power are those that can withstand a brief outage while the system transfers from the normal to standby supply. Typical loads connected to essential power include:

- Battery banks & Uninterruptible Power Supplies (UPS)
- Elevators and escalators
- Storm and ground water drainage pumps
- Fire booster pumps
- Fire ventilation systems
- HVAC systems – when room overheating conditions can cause system failures
- Track blowers

The designer must consult with the Engineer and Operator on whether a permanent or portable generator connection is required. If portable generators are proposed, the Engineer and Operator should be consulted to determine the optimal location of generator plug-ins and points of connectivity in the single line Design for the facility.

11.2.1.3 Critical Power (Utility, Standby, UPS & Batteries)

Critical power must be backed up by an Uninterruptable Power Supply (UPS) and/or batteries. The loads that require critical power are those that cannot withstand even a momentary outage. Typical loads requiring critical power include:

- Communications equipment, including but not limited to:
    - Network infrastructure
    - Public Address/Variable Message Sign (PA/VMS) systems
    - Closed Circuit Television (CCTV) and security surveillance
    - Smart Fare Vending Machines (SFVM) and Smart Fare Validators (SFV)
    - Mobile radio systems

  - Emergency phones

- Signal equipment, subsystems, and subcomponents
- TPSS protection, control, and communications
- Station emergency lighting and signage
- Tunnel emergency lighting and signage
- Life safety equipment (Fire Alarm Systems, Emergency Lighting) – should use integral batteries with normal or essential power connections for re-charge
- Power quality metering equipment
- Access Control System (C-Cure, Corporate IT)
- Building Management Systems (BMS)

The systems equipment listed above may have differing backup power requirements. Some equipment may require UPS backup, some may require direct support from rectiverters, while some may require battery backup or internal batteries. For specific backup power requirements, refer to the associated systems section.

For systems that require critical power distribution, the location of the critical power panel and equipment is dependent on the systems requiring uninterruptable power. If one or more systems require critical power, a shared power source may be considered in the UC or placed closer to the equipment (e.g. a communications room or Signal System bungalow). The Designer must consult with the Engineer and Operator to determine the optimal location and design of the critical power system.

11.2.1.4 Essential and Critical Power Requirements

- For critical systems that use distribution panels to service multiple loads, the Design must include redundant panels (A and B) to permit panel maintenance. Distribution panels should be fed from a nearby remote mount breaker panel with a voltage sensing device.

If a loss of normal power occurs, the essential and critical power systems must be designed to provide power to all areas in accordance with the following general guidelines.

Dual Utility Feeds

- If two utility feeds with independent transformers are provided with an automatic transfer scheme, then a 2-hour UPS rated for peak operation must be provided. The automatic transfer scheme must include provisions for connecting to the communications network and providing status and alarms on BMS.

Where the electrical system supply is designed with a single transformer fed by two utility feeds, the system is not classified as redundant due to the existence of a single point of failure. This system alone is not permitted for use in supplying power to essential and critical power loads.

On-Site Permanent Generators

- If an on-site generator is provided then a 2-hour UPS rated for peak operation is required. The generator set must connect to the communications network and provide status and alarms on BMS. Refer to Chapter 12, Mechanical for points to be monitored on the BMS.

Portable Generator

The Design of portable generators must conform to equipment currently operated and maintained by the Operator. This includes the voltage and the amperage of the generator, and the physical clearance area required for parking it. All portable generators must be designed with a manual transfer switch operation. Portable generators are only permitted for maintenance and back up power and do not impact battery runtime calculations.

For Urban Style Stations, system redundancy may be provided by a plug-in for a portable generator with a manual transfer switch, provided the portable generator is rated to supply the critical services of emergency lights, CCTV, fire alarms, PA, Ticket Vending Machines (TVM), Ticket Vending Validators (TVV), BMS, Smart Fare equipment, and Signal equipment.

For systems that are backed up by a portable generator, the critical power systems must be designed for 8 hours to allow time for the portable generator to be brought to site.

- If no secondary backup is provided, then 8 hours of UPS backup is required.

11.2.2 Electrical Utility Provider

11.2.2.1 Distribution and Transmission

For the majority of the LRT System, EPCOR Distribution and Transmission Inc is the utility provider. Requirements for connecting to the EPCOR system are provided in the latest version of EPCOR Customer Connection Guide and must be referred to for electrical connection and wiring design.

11.2.2.2 University of Alberta

The University of Alberta (U of A) is also designated as a utility service provider where the LRT System passes through the campus. The U of A utility and campus wide electrical design standards must apply to installations that are directly under their operational and maintenance control. The U of A must be consulted by the Designer to confirm their requirements.

11.2.3 Right-of-Way Electrical System

For electrical loads located along the LRT ROW, the electrical system distributes power directly to end devices, Power Distribution Centres (PDC), marshalling cabinets, and Signal System bungalows. Power is routed from a UC to the LRT ROW using the underground duct bank system and/or a series of raceways.

11.2.3.1 Power Distribution Centres

A PDC that is weatherproof, vandalism resistant, and environmentally controlled must be installed at strategic locations along the ROW to provide localized power to the various system components and Stations. The PDC must house the electrical equipment necessary to step down and distribute normal and essential power. The PDC may also house equipment to provide critical power to the loads, and must be located near the area being served while being easily accessible for service.

11.2.3.2 Marshalling Cabinets

Marshalling cabinets that are NEMA 3R rated, weatherproof, vandalism resistant, have a stainless steel enclosure, are environmentally heated, and with Merv-17 filtration must be installed at Urban Style Stations to provide localized power and low-tension system distribution to the various system components. Marshalling cabinet location and appearance must consider Sustainable Urban Infrastructure (SUI) requirements, however these requirements cannot preclude the cabinet from being easily accessible for service. Refer to Appendix 11A Figures 11.8 and 11.9 for marshalling cabinet details. Cabinet locations and design must be coordinated with other Designers, and arc flash studies must be completed to confirm requirements. Each cabinet must be equipped with a temperature and humidity sensor monitored by the BMS. Refer to Chapter 12, Mechanical for details.

Power Marshalling Cabinet

Power marshalling cabinets must be provided with 120/208 V main power feed from the nearest PDC. These cabinets house the electrical equipment necessary to distribute normal, emergency, and essential power to Urban Style Stations. Power marshalling cabinets may also be used for heat trace systems, low voltage lighting systems, power distribution units, and other 120 V and above systems. The use of stand-alone UPS units is not permitted.

Low-tension Marshalling Cabinet

Low-tension marshalling cabinets must be serviced with single mode fibre from the nearest fibre main and house fibre splitters, fibre patch panels, media convertors, Access Control Units, PA systems, BMS, and any other equipment below 90 V system. All field devices should be fed with fibre in the field, with media converters mounted either in the cabinet or near each field device.

11.2.3.3 Signal Bungalows

Signal bungalows house the necessary equipment required to power crossing controls, Signal devices, and track switches. Signal bungalows must be powered from a ROW PDC with 120/240 V_{AC}. The PDC that powers the bungalows must be fed essential power from a UC electrical room. Signal bungalows must be equipped with a portable generator connection and manual transfer switch. Refer to Chapter 7, Signals for additional bungalow details.

11.2.3.4 Maintenance Receptacles

Weatherproof, vandalism resistant 20 A/120 V split duplex receptacles must be installed at 30 m intervals through tunnel sections, at tunnel track switches, and at the top and bottom of each escalator. Receptacles are also required near Trackway service points, including:

- Signaling termination cabinets
- Emergency phone locations
- LRT ROW phone locations
- Switch blowers
- PDC locations

As well, weatherproof, vandalism resistant 15 A/120 V split duplex receptacles must be installed at 20 m intervals under any Platform overhangs, and at all stairway landings.

The maintenance receptacles must include a lockable cover with twist lock electrical receptacles at locations that are readily accessible by the public.

11.2.4 Design Considerations

11.2.4.1 Harmonic Mitigation

The Designer must evaluate the need for harmonic mitigation in Stations and UC, and include mitigation measures (e.g. harmonic mitigating transformers and system filters) where applicable. For facilities such as OMF buildings or facilities with large office spaces, refer to the City of Edmonton, Facility Design & Construction Consultant Manual Volume 2, for harmonic mitigation requirements and acceptable parameters.

11.2.4.2 Demand Factors

During design, demand factors must be used to establish the loading requirements of the electrical system equipment. Given the unique nature of LRT facilities, demand factors must be established on a case-by-case basis by the Designer.

For City facilities such as office buildings and warehouse or maintenance buildings; refer to the City of Edmonton, Facility Design & Construction Consultant Manual Volume 2 for demand calculations.

The Designer must be aware of and account for loads from Operator specified equipment (e.g. cranes and equipment elevating devices, or electric vehicle charging stations).

11.2.4.3 Spare Capacity

The electrical system must be designed for the known load requirements plus an additional 30% load capacity for future expansion. Distribution panels must reserve 25% of the panel physical space for future circuit requirements.

11.2.4.4 Panelboard Locations

Panelboards must be located near the area being served and should be in a non-public service area. Where practicable, panelboards should be located at a level to facilitate servicing. Panelboards should be placed in service rooms dedicated to the electrical system.

11.2.4.5 Third Party Panelboards

For third party services such as advertising panels, vending machines, and ATMs the Designer must provide a dedicated panel for those services. Third party panels must follow the requirements of 11.2.4.3.

11.2.5 Studies and Calculations

The following analyses, studies, and calculations must be applied to the Design of new electrical system installations:

- Short circuit and fault analysis
- Protection and coordination study
- Arc flash and incident energy study
- Lightning/surge analysis
- Lighting level study
- Voltage drop analysis
- Heat rejection analysis
- Battery Run Time Calculations

11.2.5.1 Short Circuit and Fault Analysis

A short circuit and fault analysis must be performed to confirm that all electrical equipment and cables are rated for the maximum available fault currents on the system. The analysis must be performed using a recognized software package such as SKM, ETAP, or an equivalent approved by the Engineer.

11.2.5.2 Protection and Coordination Study

A protection and coordination study must be performed to confirm that all electrical equipment and cables are protected, and all protection elements are coordinated under ground and/or phase fault conditions.

11.2.5.3 Arc Flash and Incident Energy Study

An arc flash study must be performed to identify the specific arc flash hazard for the electrical equipment. The study must calculate the incident energy (arc flash energy). The study must minimize arc flash energy levels without creating nuisance tripping during ground and/or phase fault conditions. Refer to the City of Edmonton Facility Design & Construction Consultant Manual – Volume 2 Appendix E for details.

11.2.5.4 Lightning/Surge Analysis
A lightning/surge analysis must be performed to confirm that lightning and surge protection devices are correctly placed and adequately designed to withstand the maximum lightning and surge values. The Designer must use the Installation Code for Lightning Protection Systems (CSA B72) standard to evaluate if the project requires a lightning protection system and bring to the attention of the City and Engineer. If required, further design drawings must be prepared in accordance with the standard.

11.2.5.5 Lighting Level Study
A lighting level study must be performed to confirm that the required lighting levels and light coverage are provided for all indoor and outdoor applications.

11.2.5.6 Voltage Drop Analysis
A voltage drop analysis must be performed to confirm that voltage levels to distribution panels and end devices are adequate under worst case load conditions.

11.2.5.7 Heat Rejection Analysis
A heat rejection analysis must be performed for all systems rooms and cabinets to confirm that adequate heating and cooling are provided to meet the required operating temperatures of the equipment. The Designers must provide summary tables containing the heat rejection numbers for the equipment housed in the cabinets or rooms for use by the Mechanical Designer. The tables and associated calculations generated by this analysis must be provided with the cabinet and room drawing packages. Refer to Chapter 12, Mechanical for specific requirements.

11.2.5.8 Battery Run Time Calculations
Battery run time calculations must be performed on all battery systems that are considered critical power. The run time calculations must be based on typical equipment loading if specific loading is unknown. The calculations, their associated summary tables, and any assumptions must be provided with the battery system drawing package.

11.3 MATERIALS AND IDENTIFICATION

11.3.1 Materials

11.3.1.1 General
Material and device selections must be based on the following:

- Use of materials impervious to corrosion and resistant to the effects of water and chemicals that may be present
- Minimizing maintenance or avoiding failure during the long service life expectancy of the LRT System and Ancillary Facilities
- Being capable of withstanding rough usage and vandalism common to public facilities
- Being resistant to the efforts of unauthorized persons attempting to remove installed equipment during and after construction
- Use of standardized devices and materials to the greatest degree practicable when currently in use in similar applications throughout the LRT System

All materials proposed in the Design must have existing CSA approval. If CSA approval has not been obtained, then acceptance for material use must be obtained from the Engineer and/or the Authority Having Jurisdiction (AHJ).

All electrical fittings, supports, hanger rods, pullboxes, channel frames, conduit racks, outlet boxes, brackets, and clamps must have a hot dipped galvanized finish or powder coated enamel paint finish over a corrosion-resistant primer. In existing facilities or in areas with severe environments, the Designer must discuss with the Engineer and Operator if stainless steel or marine grade aluminum should be used.

All enclosures located outdoors, in a tunnel or trench, or on a Grade Separated structures must be made of stainless steel. All fittings, covers, bolts and hinges associated with these enclosures must be made of stainless steel.

All interior panelboards, distribution centres, motor control centres, and transformers must be factory finished in alkyd high gloss enamel paint applied over corrosion-resistant primer.

11.3.1.2 Spare Parts

The Designer must provide a recommended spare parts list for each component, for review and acceptance by the Engineer.

11.3.2 Identification

Colour coding, identification, and methods of paint finishes to electrical equipment must be specified and carefully supervised during supply and construction.

The extent of tagging of electrical equipment and systems must be discussed in detail with the Engineer in consultation with the Operator prior to specification. A cable and conduit schedule must be developed as part of the Design with field level cable and conduit labels identified and unique to the location they are installed in.

11.3.2.1 Colour Coding of Systems Elements

System colours, including all associated equipment enclosures, terminations, pullboxes, couplings, Junction boxes, and covers must be as follows:

Table 11.1 System Elements Colour

Application	Colour	Colour Code	Labelling Designation
Above 750 V	Grey	RAL 7001	
347/600 V	Sand	RAL 1001	
120/208 V	Grey	RAL 7001	
Essential System	As per Voltage		“EM”
Critical Power from UPS Unit	As per Voltage		“UPS”
Fire Alarm	Red	RAL 3001	“FA”
Data Systems	Blue	RAL 5005	“C”
Telephone	Blue	RAL 5005	“T”
Intercom Systems	Yellow	RAL 1003	“I”
PA/VMS	Green	RAL 6032	
CCTV	Yellow	RAL 1003	
Card Access	Yellow	RAL 1003	“CA”
Low Voltage Switching	Black	RAL 9004	“LV”
Solar PV Systems	Gold	RAL 1003	

Transformer enclosures must be finished in accordance with the primary voltage colour as outlined above.

11.3.2.2 Identification Labelling

Lamicoid nameplates must be 3 mm thick plastic engraving sheet and must be mechanically attached.

- Normal Power: Black face, white core for lettering
- Essential Power: Red face, white core for lettering
- Critical Power: Yellow face, black core for lettering

The size of labels for Lamicoid nameplates must be:

- Size 1: 12 mm high with 5 mm high letters
- Size 2: 20 mm high with 8 mm high letters
- Size 3: 25 mm high with 12 mm high letters

Table 11.2 below provides general guidance for identification labelling; the Designer must coordinate specific labelling details with the Engineer prior to preparing labels.

Table 11.2 System Nameplate Designation

Equipment	Nameplate Identification	Lamicoid Nameplate Size
Main Distribution Center	Building name, consulting engineer, date installed, amperage, voltage, phase	3
	Main breaker, metering cabinet	2
	Instrument transformer enclosure	2
	Loads controlled by each overcurrent protective device	1
	Metering devices	1
Distribution Centers	Distribution center designation Amperage, voltage, phase Fed from	2
	Loads controlled by each overcurrent protective device	1
Panelboards	Panelboard designation Amperage, voltage, phase	2
Ground Bus	System ground	1
On/Off Switches	Load controlled	1
Disconnect Switches, or Starters, Contactors	Amperage, voltage Equipment controlled Panel & Circuit details	2
Splitters	Amperage, voltage Fed from	2
Transformers	Transformer designation Capacity Secondary and primary voltages Load side Panel and Circuit # Line side Panel and Circuit #	2

Equipment	Nameplate Identification	Lamicoid Nameplate Size
Standby Power Equipment	Designation Amperage, voltage	3
Wireways	Designation Voltage	2
Conduits	System designation To-destination description Panel & Circuit details	1
Junction boxes	Designation Voltage	1
Line Voltage Cabinets and Enclosures	Designation Voltage	2
Low-Voltage Cabinets and Enclosures	System name System number if more than one cabinet or enclosure	2
Enclosures	System designation Major components within cabinets and enclosures	1

11.3.2.3 Wire Identification Materials:

Wire identification must use one of the following:

- Heat shrink sleeves, blank
- Clear plastic tape wrap-on strips with white writing section
- Wrap-on strips, pre-numbered
- Slip-on identification bead markers or sleeves, blank or pre-numbered

11.3.2.4 Conduit Identification Materials:

Conduit identification must use 3 mm thick plastic engraving sheet, black face, white core lamicoids and must be mechanically strapped.

11.3.2.5 Colour Coding of Conductors

Conductors must be colour coded throughout a facility with the same colour applying to the same phase throughout. Colour coding must be by insulation colour or permanently applied colour banding at all distribution centres and panels. The Designer must refer to and follow the CEC section 4-032: Identification of insulated conductors.

11.4 EQUIPMENT

11.4.1 Motors

Motor supply voltage requirements are based on the power rating as follows:

- Fractional sized motors up to and including ½ HP (0.37 kW) must be 120 V, single phase powered with integrated thermal overload protection
- Fractional sized motors greater than ½ HP (0.37 kW) up to and including 1 HP (0.75 kW) must be 208 V or 600 V, three phase powered
- Motors larger than 1 HP (0.75 kW) must be 600 V, three phase powered

In addition, motors used with variable speed drive applications must be inverter duty rated and all motors must be high efficiency. The implementation of these requirements must be closely coordinated with the mechanical Designer. Refer to the City of Edmonton Consultant Manual Volume 2 – Technical Guidelines for motor requirements.

11.4.2 Transformers

For all non-systems specific transformers, the Designer should refer to the City of Edmonton Consultant Manual Volume 2 – Technical Guidelines for transformer requirements. For systems specific transformer requirements the Designer should refer to the relevant sections of these guidelines.

Transformers with the secondary voltage less than 600 V may be ceiling mounted up to and including 75kVA. Ceiling mounting systems must be coordinated with the Structural Designer. Transformers over 75kVA must be floor mounted with neoprene vibration isolation pads and with flexible conduits for final connections. Transformers must be dry type construction, with a TP1 energy star rating, and C802.2 compliant.

All outdoor transformers must be installed in properly rated NEMA enclosures to protect the transformers from the elements and from rodents. The cabinets must be designed to permit the transformers to operate at their maximum capacity over the entire ambient temperature range as identified in Chapter 1, General. Adequate ventilation and fans may be required. If outdoor transformers are lightly loaded under normal operating conditions, the Designer must determine if the transformer enclosure requires external heaters to maintain acceptable operating temperatures.

11.4.3 Disconnect Switches and Fuses

Disconnect switches, complete with lockout, must be provided for all motors. Fused disconnect switches should not be used. Circuit breakers must be used if protection is required.

Three phase disconnect switches must be quick make - quick break, three pole, three or four wire type complete with a bonding lug. In general, the switch enclosures must conform to EEMAC with types suitable for the proposed application and environmental conditions.

11.4.4 Manual Transfer Switches

Manual transfer switches are only permitted to accommodate portable generators. The manual transfer switch must be able to inhibit, alert, and alarm against phase rotation errors. The manual transfer switch must be interlocked with the normal power supply such that the interlock on the normal power supply must be opened before the manual transfer switch can be closed into the portable generator power supply.

11.4.5 Automatic Transfer Switch

In all cases where a standby source is permanently located at a site and is operational, a CSA approved high speed contactor or circuit breaker transfer switch must be provided. Molded case switches with integral protection are acceptable.

Transfer switches must:

- Use electronic control circuitry for system operation and monitoring
- Contain a microprocessor-based transfer logic controller
- Include provisions for connecting to the communications network and BMS for status and alarm monitoring (Refer to Chapter 12, Mechanical for details on BMS monitoring requirements)
- Be high speed open transition, break-before-make operation type
- Be equipped with a bypass switch feature

- Be of 4-pole design for switching the current carrying conductors of each phase and neutral as per CEC requirements
- Be designed to avoid nuisance tripping on ground fault protection schemes

11.4.6 Permanent Standby Generators
Standby rated fixed generators must be installed to provide essential power in the event of a power failure where a standby source is not available or additional on-site backup power is required. In general, the requirement for a permanent emergency generator must be reviewed on a location-specific basis at the outset of the design stage.

11.4.6.1 Standby Generators
Standby generators must comply with the latest CSA-C282 standard for emergency electrical power supply in buildings. Generators must be diesel fueled; natural gas generators are not acceptable.

Generators and day tanks must be located in a dedicated room within a UC or similar building. The fuel tank must be sized for the generator to run for at least 24 hours without refueling. The tank must not be buried. Fuel fill stations must be designed in coordination with the mechanical Designer and must be located on the outside of the building where access is provided for a fueling truck.

Generators must not be placed in the same room as other systems equipment. The room and generator footprint must be sized for a generator that meets the needs of the Station or facility with an allowance for future loads. At minimum, a 1 m clearance must be maintained to walk around the generator. All maintainable parts on the Generator must be accessible from floor height including if a sub-base fuel tank is used. Where access from the floor is not practicable, special provisions must be designed to allow service from a step or platform.

The generator set must include provisions for connecting to the communications network and BMS for status, alarm, and safety indicator monitoring. Refer to Chapter 12, Mechanical for details on BMS monitoring requirements.

Refer to the City of Edmonton, Facility Design & Construction Consultant Manual Volume 2 for further requirements.

11.4.6.2 Standby Generator Replacement
Permanent standby generators must be located to permit a future service replacement. This requirement may include a planned path with adequate structural rating and clearances around corners and through doors. Consideration must be given for dollies and/or potential rigging requirements to skid or skate the generator into and out of the facility.

11.4.7 Portable Generators
In Stations and Ancillary Facilities where essential power is not provided or additional power backup is required, a manual transfer and an emergency Power Distribution System (PDS) must be provided to allow the Operator's 600 V_{AC}, three phase, 60 kW, portable generators to provide backup power. The generators can support both 600 V and 120/208 V services. The Designer must confirm the generator ratings and load capabilities with the Operator.

A manual transfer system must be provided with a weather-proof receptacle compatible with the Operator's existing portable generators. Where practicable, the transfer system must be installed inside the building or enclosure. The transfer system must incorporate over-current protection and reverse rotation protection. The exterior plug-in must be enclosed in a weather proof NEMA4 rated cabinet, with an Appleton Powertite series pin and sleeve style receptacle. The exterior plug-in location must be finalized based on discussion with the Operator to coordinate truck access to the plug-in. The backup power tie-in assembly including the generator receptacle must be located adjacent to At-Grade Platforms and have sufficient space to house the generator without unduly impeding pedestrian, cyclist, and vehicular traffic or causing a safety hazard.

The manual transfer must be designed using a Kirk key system or approved equivalent to prevent accidental interconnection of the portable generator with utility lines.

11.4.8 Distribution Panelboards

Panelboards must be located in each service room within UC buildings and Stations to serve local loads. Panelboards in Urban Style Stations must be located in the marshalling cabinets.

Power panels, lighting panelboards, and switchboards must be CSA approved for sprinkler environments and NEMA rated for the environment they are being installed in, except in marshalling cabinets. All panelboards on one site must be from one manufacturer.

In addition to CSA requirements, the manufacturer's nameplate must show the fault current that the panel, including breakers, has been built to withstand.

Panelboards must have a copper bus with neutral of the same ampere rating as mains. Mains must be suitable for bolt-on breakers. Panelboard trim must include concealed front bolts and hinges.

Breakers must be thermal and magnetic tripping in panelboards except where indicated otherwise. When mounted vertically, the down position must designate an open breaker. Breakers must be lock-on devices for fire alarm, security system, and main breakers feeding UPS units. Molded case circuit breakers must be bolted to the bus; stablock or pressure fit style breakers are not permitted.

Where loads are being added or modified in existing panels, the Designer must review the revised loading and include the revision of breaker sizes, loading, and descriptions in the panel schedule which should be provided in the Contract documents. If the panel is fed by UPS or battery banks, then runtimes must be evaluated to confirm facility requirements are being met.

11.4.9 Equipment Clearance

Clearance around electrical and systems equipment must meet minimum CEC clearance requirements for egress and operations. To ensure clearances are maintained post construction, a clearance envelope must be painted on the floor in yellow paint.

11.5 UNINTERRUPTABLE POWER SUPPLY (UPS)

A UPS must be an online solid state, fully automated device that must operate in conjunction with the normal and essential electrical systems to provide uninterruptible power conditioning in both AC and DC form, backup and distribution for miscellaneous critical loads. The backup duration of the UPS must be based on the application and the normal and essential power system feeding the UPS. Typically, the UPS must be sized according to the following scenarios:

- Dual utility or permanent generator supply available – UPS rated for two hours at 100% load
- No dual utility or permanent generator supply available – UPS rated for eight hours at 100% load

The UPS must be designed to operate on utility and generator power. The UPS must connect to the communications network and BMS for status, alarm, and safety indicator monitoring. Refer to Chapter 12, Mechanical for details on the BMS monitoring requirements.

The Designer must coordinate potential multiple UPS requirements (e.g. communications, Signals, TPSS) in the Design.

The Communications systems must be designed based on the Alpha Technologies product line for both AC and DC systems. Refer to the Alpha Technologies Design Standards document for details.

11.5.1 Maintenance Bypass Switch

For UPS installations, an automated wrap around, wall mount maintenance bypass switch must be incorporated into the UPS system Design to allow the UPS to be bypassed without disruption to service. The bypass must allow the entire UPS to be removed from service for maintenance or replacement. The switch must be sized to carry the entire load of the UPS when in bypass.

The maintenance bypass switch set must include provisions for connecting to the communications network and BMS for status, alarm, and safety indicator monitoring. Refer to Chapter 12, Mechanical for details on the BMS monitoring requirements.

For the communications system, the maintenance bypass must be by Alpha Technologies, type XMBS. Amperage must be as per system requirements. Refer to the Alpha Technologies Design Standards document.

11.5.2 AC Plant

For communications systems, a HP-2 Amps Plant, by Alpha Technologies should be used for providing critical power to subsystems and subcomponents that require AC feeds. Refer to the Alpha Technologies Design Standards document for detailed design requirements.

For UC locations where a data centre is required, dual AC Plants must be provided to achieve 2N configuration.

11.5.3 DC Plant

For communications systems, a DC CXPS Plant, Smart E2 modules and E-Limiters by Alpha Technologies should be used to provide critical power to subsystems and subcomponents that require DC feeds. Refer to the Alpha Technologies Design Standards document for detailed design requirements.

For UC locations where a data centre is required dual DC Plants must be provided to achieve 2N configuration.

11.5.4 Battery Charger

Battery chargers must be specifically designed for the batteries they are required to charge. Each rectifier/charger must bring the batteries to full charge from complete discharge within 24 hours when delivering full rated load and four hours when operating at half rated load. The chargers must be equipped with the necessary protection and control to maximize battery life and protect the batteries. The Designer must account for battery recharge amperage when sizing the system.

11.5.5 Batteries

Batteries must be suitable for the environment, service conditions, and expected cycling of load. The batteries must be recombinant and be factory assembled in an isolated compartment or in a matching cabinet, complete with battery disconnect switches.

Batteries may be sealed valve regulated lead acid (VRLA) or Lithium Ion (LI). The Designer must coordinate with the Operator on battery types during design.

Batteries must be rated for runtime base on the power infrastructure available of 2 hours or 8 hours. The maximum recharge time on batteries must be under 24 hours.

Any system using a battery bank must include temperature monitoring with temperature alarms indicating when the batteries are exceeding their maximum operating temperature.

The Designer must coordinate ventilation requirements for battery off-gassing and heat rejection with the mechanical Designer.

Battery units specified for Communication Systems must be rack mount C&D, Tel-12-210F with 48 V_{DC} output. Refer to the Alpha Technologies Design Standards document.

11.5.5.1 TPSS

Refer to Chapter 6, Traction Power for battery requirements specific to TPSS.

11.5.5.2 Signal Bungalows and Cabinets

Refer to Chapter 7, Signals for battery requirements specific to Signal bungalows and cabinets.

11.6 ELECTRICAL HEAT TRACE SYSTEMS

11.6.1 General Requirements

Heat tracing must be provided for the following elements when they may be exposed to temperatures below freezing:

- Eavestroughs
- Roof drains
- Rainwater leaders
- Gutters
- Drainage troughs at portal entrances
- Drainage catchments at pedestrian ramps and stairs
- Water lines
- Sanitary drain lines
- Storm water drain lines
- Dry line sprinkler drip valves

Heat tracing must be provided where low temperatures may cause ice build-up in the track drainage system located in underground structures. For additional details on heat tracing requirements, monitoring and control points, and locations refer to Chapter 12, Mechanical.

All heat tracing systems must be a simple contactor base with a 24 V control coil connected to the BMS for operation. Heat trace controllers are not permitted. Heat trace cables must be designed for a 120/208 V system and use of a 600 V system should be avoided where practicable. The contactor and coil assembly must be contained in an enclosure and must be clearly labeled. In Urban Style Platforms, the heat trace elements must be housed within the power marshalling cabinet. 600 V heat trace systems currently exist on the LRT System. The Designer must determine the system voltage prior to any re-design or renovation to a heat trace system.

11.6.2 Cables

Heat tracing cables must be self regulating for freeze protection on pipes and drains, and be mineral insulated with stainless steel or alloy 825 sheath for installation when embedded in concrete. The cables must be supplied by a recommended voltage rating of either 120 V or 208 V and have cold leads of sufficient length to run from in-feed points to power connection boxes.

11.6.3 Power Services

The heat tracing system must be supplied from panelboards with ground fault interruption built into the breaker. All power connections in feed and junction boxes must be appropriate for their location. If located outdoors or in tunnels feed and junction boxes must be watertight enclosures appropriate for accepting either in-slab or surface conduit entry.

11.7 FIRE ALARM AND DETECTION

Fire alarm and detection systems must be provided for all enclosed facilities, including UC buildings, stand-alone TPSS buildings, buildings with fire suppression systems, and Stations with enclosed underground Platforms as well as tunnel sections requiring ventilation. A fire alarm system must also be provided in Stations with adjacent Transit Centres. Urban Style open Platforms do not require a designated fire alarm system, unless deemed necessary by code or design requirements.

Where a fire alarm system is installed, it must be an addressable system and ULC rated for emergency evacuation. Dedicated hard wired phone line and cell phone based autodialers must be provided and connected to an authorized third-party monitoring service. Auto dialers must be provided as a secondary means of monitoring to be connected to the LRT Operations Control Centre (OCC). Convenient access to the fire alarm speaker system must be provided for Edmonton Fire Rescue Services (FRS) and Emergency Medical Services (EMS) use at all annunciator panels. Annunciator panels must be installed with a flush mounted polycarbonate (Lexan) shield to minimize vandalism.

The fire alarm annunciator must be located at each designated street address entrance to the facility complete with a panel indicating fire alarm zones and system status.

Based on the planned occupancy of a facility or building the Designer must review the benefits of designing for a single stage or dual stage system with the Engineer. The review must include the benefits and disadvantages of each system type. This decision is crucial in facilities with dry chemical suppression systems to prevent unnecessary discharge.

Automatic shutdown of air systems and elevators must be incorporated into the fire alarm system. Elevators must home to the nearest floor and then lock out until the fire alarm system has been restored. Escalators must be kept running during alarms to provide faster and safer exiting.

The Designer must give consideration to a method of preventing fire doors from closing during routine generator testing. A routine generator test momentarily shuts off the power and is identified as a power failure in the system, which may activate preventative measures such as the closing of fire doors.

Fire alarm speakers and strobes must be used for audible and visual alarms in all areas with public access and within a UC. Rough service areas such as crawl spaces and access tunnels must use fire alarm horns with strobes for annunciation.

Fire alarm requirements must be coordinated between the electrical system Design and the tunnel Design for Stations that include tunnel approaches. The Designer must confirm all detection and alarm methodologies in consultation with the Engineer.

11.7.1 Area and Room Requirements

High significance or critical rooms such as main server/data centres, communication rooms, Signals rooms and stand-alone TPSS buildings may require very early detection systems (VESDA) and dry chemical suppression systems. The Designer must review requirements for these rooms with the Engineer for intent and feasibility. Such systems must be monitored and form part of the main fire alarm system for the facility. Where a VESDA system is proposed, one reference detector per facility must be provided to monitor outdoor smoke obscuration. Coordination with the mechanical Designer is required to confirm how the suppression release is designed.

Where crawl spaces are proposed, the current ABC [152] must be consulted to confirm if fire protection is required based on area classification. If fire protection is deemed necessary for the crawl space, the devices must be rated for use in high moisture areas.

All public washrooms must be equipped with a rate of rise heat detector. All Train Operator (TO) washrooms must be equipped with a smoke detector.

11.7.2 Installation Requirements

All conduits for fire alarm and detection systems must have a pull cord installed in them at the time of construction. Spare pull cord must be provided in conduits between annunciator and fire alarm cabinets.

The fire alarm and detection system Design should allow for spare zones for possible future expansion of retail space or additional services.

Manual pull-stations in public areas must have covers to limit vandalism and misuse.

The Design must include an exterior audible and visual fire alarm indicator at each building.

All fire detectors, unless precluded by the environment in which they are placed, must be of the addressable type.

All fire alarm cabling must be approved by the fire alarm manufacturer. All fire alarm cabling must be installed in rigid conduit. Renovations requiring the use of flexible conduit may only be used with prior approval from the Engineer.

The fire alarm system must provide a supervised signal for general alarm and general fault to the BMS. Refer to Chapter 12, Mechanical for further details.

Refer to the City of Edmonton, Facility Design & Construction Consultant Manual Volume 2, Appendix F – Fire Alarm Communication Design Guidelines for details on Fire alarm methodology for monitoring and Auto Dialer installations.

11.8 LIGHTING

The lighting guidelines presented in this section provide the functional requirements for site areas, pedways, Stations and related service areas, tunnels, portals, Open Trackway, and parking facilities including Park and Ride lots.

The Design must provide lighting levels that meet requirements for quality, convenience, efficiency, and system safety. Ease of maintenance must be a primary consideration in the selection of lighting systems and devices.

11.8.1 General Design Objectives

The Design must provide lighting systems that have good colour rendition and are of high quality suitable for hard usage applications. The Designer should select readily available, low maintenance, long life luminaires with high power efficiency. For Light Emitting Diode (LED) fixtures the L70 rating should be a minimum of 70,000 hours.

Where access to the light sources is difficult, the Designer should consider mounting remote ballasts and drivers in an accessible location. Luminaires must be suitable for their environment and must be resistant to vandalism and theft.

Luminaires must have Ultra-Violet (UV) stabilized polycarbonate diffusers such as Lexan or an approved equivalent. Glass luminaries are acceptable for installations that are not accessible to the public. Lighting design principles for Stations are presented in Chapter 10, Stations and Ancillary Facilities. These principles may also be applied to other components of the LRT System that require lighting.

Refer to the City of Edmonton Road and Walkway Lighting Manual [209] and the Guide for the Design of Roadway Lighting [210] for lighting standards for Street infrastructure. Coordination with an independent street lighting designer and contractor may be required in overlapping areas.

11.8.2 Performance Standards

All luminaires must be commercial/industrial grade, and all tunnel, underpass, and exterior luminaires within the LRT ROW must be IP 66 rated.

In general, lighting products must be specified for the environment they are being installed in. Areas that may be susceptible to high humidity or water ingress must use lighting products rated for damp or wet locations. The average to minimum uniformity ratio for interior lighting must not exceed 3:1. For exterior sidewalk, Shared Use Path (SUP), cycle track, and roadway lighting, the minimum uniformity ratio must be 6:1.

The colour temperature (in Kelvin) of luminaires must be discussed with the Engineer to be consistent throughout the Stations and Ancillary Facilities on the LRT System. In general, interior lighting must be between 3500 K and 4000 K color temperature. Exterior lighting must be between 3000 K and 3500 K. Lighting at Urban Style Stations should be between 3500 K and 4000 K. The Designer must coordinate with the facilities Designers to meet their design intent.

All luminaire hinging mechanisms must be metallic; plastic is not permitted.

Luminaires must minimize glare to avoid visual impairment of Patrons, pedestrians, cyclists, and motor vehicle operators.

11.8.3 Standard Lighting Elements/Fixtures

11.8.3.1 Lighting Sources

LED lighting should be used for all lighting Designs, however there may be locations where other lighting sources may be considered. The Designer must provide recommendations for lighting sources to the Engineer for review and approval.

Guarded or vandal resistant luminaires must be used to protect lighting in areas where there is a significant potential for vandalism or breakage, particularly in public use areas or utility areas requiring low mounting heights.

The light source selected must be based on application, lamp life, source lumen efficacy, ease of maintenance, color spectrum, and illumination control (photometric data).

A white light source is required to provide improved visibility and color rendering on Platforms. All lighting at Stations and for a UC must be backed up by a redundant power source. 10 Lux minimum lighting for egress as per ABC must be provided throughout the Stations and Ancillary Facilities. Refer to minimum and emergency light levels in Section 11.7.4. Light tube lighting is not permitted.

Safety chains fastened to a roof or ceiling should be considered in public areas to minimize the possibility of overhead lighting falling. The Designer should consider the type and location of the luminaire, and the potential for vibration in assessing the need for safety chains.

11.8.3.2 Lighting Ballast

Lighting ballasts and drivers must be readily accessible through the luminaire opening or remotely mounted for ease of maintenance. Closed units, such as sign boxes or display cases, must have adequate ventilation to dissipate ballast and lamp heat.

11.8.4 Illumination Levels

In general, minimum lighting levels (except where otherwise noted) must be provided at a height of 900 mm above the finished floor level of the facility or area being lit.

The following minimum illumination levels have been established through the experience gained by the Operator over the LRT System operational timeline. Illumination levels should be reviewed with the Engineer and Operator in conjunction with Corporate Security and CPTED [198] reviews for each site during design.

Table 11.3 Interior Spaces

Location	Average Minimum Lux	Minimum Emergency Egress Lighting as per ABC	Average Minimum Operational Lux under Normal power outage (if available on Generator[5] or UPS)
Public Circulation Areas[1]	350	10	150
Platforms (above- & At-Grade)	300	10[6]	150
Platforms (below-grade)	350	10	150
Heated Shelters	350	10[6]	150
Interior Stairs, Ramps, Escalators	350	10	150
Elevators Entrance & Interiors[2]	350	10	150
Service Rooms[3]	500	10	250
Washrooms	350	10	150
Crawl Spaces[4]	150	10	60
UC Corridors	150	10	60

Notes:

1 Public circulation areas include passageways, pedways, entranceways, mezzanine levels, and ticketing areas

2 Coordinate with elevator supplier

3 Including TPSS, communications, Signals, electrical, mechanical, high voltage, generator, outside service provider room

4 Luminaires must be damp location rated
5 Life safety on generators will require separate ATS and should not be used
6 Not required for open At-Grade platforms with full glass shelters; coordinate with Architect and base on Code analysis

Table 11.4 Exterior Spaces

Location	Average Minimum Lux	Minimum Emergency Egress Lighting as per ABC	Average Minimum Operational Lux under Normal power outage[2] (if available on Generator[4] or UPS)
Stairs[3]	200	10	100
Exterior Walkways/Ramps connected to Stations[3]	50	10	25
Private Vehicle/Taxi Drop-off	25	N/A	N/A
Plaza Areas/Walkways to Stations[3]	25	N/A	N/A
Amenity Areas (e.g. bike racks, benches)	25	N/A	N/A
Surface Public Parking Lots	25	N/A	N/A
Transit Centre Islands	20[1]	N/A	N/A
Entry Man Doors	50	N/A	N/A
Exterior Perimeter around UC Buildings	10	N/A	N/A
UC Parking areas	10	N/A	N/A

Notes:
1 Transit Centre Design Guidelines
2 These are reduced lighting levels under normal power loss to continue operations on an emergency power source
3 The Designer must consult with the Engineer on egress pathways and exterior circulation areas used for exiting and provide a higher level of illumination to exceed the ABC requirement to accommodate safety and security parameters
4 Life safety on generators will require separate ATS and should not be used

Table 11.5 Trackway

Location	Average Minimum Lux	Minimum Emergency Lux
Open Trackways:		
No Barrier[2]	10	N/A
Soft Barrier	10	N/A
Hard Barrier	10	N/A
LRT ROW Equipment Areas[3]	20	N/A
Tunnels - Trackway and Emergency Egress Walkways (including Catwalks)[1]	20	10
Cross-Connections	20	10
Track Switches	40	N/A
Grade Separation (short underpass) [2]	20 to 50 nighttime	10

Notes:

1 Lighting within tunnels must provide for safe egress in an emergency and sufficient illumination levels for operational and maintenance purposes

2 IESNA RP-8-18 [211] and the Transportation Association of Canada (TAC) Guide for the Design of Roadway Lighting [210] must be used as a guideline for lighting levels used for this application. The illuminance values are minimum and the Designer must establish these values for each with the Engineer and the Operator

3 Provide lighting around LRT ROW equipment such as network utility boxes, power distribution cabinets, and Signal bungalows to deter equipment vandalism

11.8.4.1 Tunnel - Portal Transition

The Designer must give special consideration to the transition of lighting levels from daylight to darkness at tunnel entrances. The length of threshold/transition lighting must be based on LRV operating speeds and the corresponding safe stopping distance. The Designer must review the American National Standard Practice for Design and Maintenance of Roadway and Parking Facility Lighting – ANSI/IESNA RP-8-18 [211] and the Guide for the Design of Roadway Lighting [210] and consider the given criteria in their lighting Design.

For tunnel lighting the Designer must incorporate a graduated light Design where the lighting transitions daylight to dark lux values. Table 11.6 below shows the anticipated transition lengths and lux values.

Table 11.6 Tunnel Transitions

Zone	Distance from Portal	Daytime Lux	Nighttime Lux
1	0 to 30 m	5000	20
2	30 to 60 m	500	20
3	60 to 90 m	50	20
4	Greater than 90 m	20	20

For additional guidance the Designer must refer to the IES Lighting Handbook [205]. The Designer must coordinate with the Engineer to verify that the proposed lighting levels are acceptable and appropriate for the application.

11.8.5 Lighting Control Systems

Low voltage lighting controls must be operated by a simple relay-based system. For complex facilities and/or if a network system is required, the system must be DMX lighting protocol based. Any other type of low voltage system must be reviewed and approved by the Engineer prior to Design development. Low voltage lighting controls must be monitored and controlled by the BMS. Refer to Chapter 12, Mechanical for further details.

Low voltage lighting control panels in a UC must be located in the electrical room with operable switches in each room. Low voltage lighting control panels on Urban Style Platforms must be located in a marshalling cabinet or in Electrical closets/rooms for above- or below-grade platforms.

NECB Part 4 for lighting must be followed for switching arrangements. The Designer must coordinate the switching arrangements with the facility users through the Engineer to confirm that the appropriate controls are being specified in accordance with NECB.

At-Grade or above-grade Platforms must incorporate daylight harvesting to dim lights accordingly while maintaining minimum light levels specified for the area.

Exterior luminaries, including luminaries in signage, must be controlled by photocells and the BMS. Exterior light control must include a maintenance bypass switch (Hand-Off Auto).

For upgrades or renovations in existing facilities, the Designer must consider the existing lighting and switching arrangements and develop a plan to extend existing systems. Stand-alone systems should not be used. Coordination with the Engineer is required during design to identify existing issues that may be mitigated through the Design.

11.8.6 Lighting Energy Conservation Measures

As per City Policy C532, LEED protocols [10] must be used where applicable and practicable. Innovations to reach acceptable lighting levels while lowering operating costs are encouraged subject to the Engineer’s review and approval.

11.8.7 Emergency Lighting

Emergency egress lighting systems must be provided as required by code. Regardless of the power supply sources available, electrical rooms and generator rooms must be equipped with a minimum of one self-contained battery pack with light heads.

Egress and emergency lighting must always be provided through CSA approved battery units for life safety equipment. These battery circuits may be powered through on-site generators, however, powering the life safety lights directly from the permanent generator must be avoided. If life safety lights are being directly powered from a generator, then the generator must be CSA 282 compliant with a separate AutomaticTransfer Switch (ATS) for life safety equipment.

11.8.7.1 Power Supply Sources

If essential power is available through a utility back up to the normal feed, then all lighting in a UC or Station must be connected to the essential power feeds. If normal power is compromised, the redundant power feed must pick up the entire load.

If a permanent generator is available, then a minimum 40% of the operational lighting in a UC or Station must be connected to the generator.

If a redundant utility feed and permanent generator are not available, and backup power is provided from a portable generator, then a lighting UPS must be provided to power a minimum 40% of the operational lighting in in UC and Stations. The UPS capacity must be sized to pick up load for a minimum of 2 hours with 25% spare capacity.

The Designer may be required to provide multiple lighting circuits to meet the above requirements. This arrangement must provide the required illumination in all areas if normal utility feeds in the area are compromised. The Designer must review this requirement with the Engineer at the outset of design to confirm the percentage of operational lighting that can be achieved. The minimum egress lighting of average 10 lux by code must be provided using battery packs.

11.8.7.2 Emergency Lamp Types

Emergency lighting lamp sources must be LED. For renovation projects, the designer must consider the existing emergency fixture types as they may be incandescent quartz, induction lamp, or fluorescent technology. The Designer must coordinate with the Engineer to evaluate replacement of fixtures to LED lamp technology.

Instant restrike devices used in conjunction with high intensity discharge lamps must be reviewed to confirm reliability and lamp maintenance. Results of the review must be provided to the Engineer for acceptance.

11.8.8 Crew Advisory Lights

Trackways within a tunnel and/or on Grade Separated structures must be equipped with amber warning lights to advise the TO of a possible work crew within a specific track section. Zones may be created based on the overall length of the track within the tunnel or on the structure. The exact location of lights must be coordinated with the Engineer and Operator. Lights must be powered from the nearest PDC and controlled and supervised through the BMS. Refer to Chapter 12, Mechanical for BMS details.

11.9 METERING

Panelboards or switchgear incorporating metering equipment must be constructed so that all meters and transformers used with meters are accessible. Metering transformers must not be installed in the rear section of a cubicle unless the cubicle is accessible from the back.

11.9.1 Utility Metering

The utility service provider must be consulted to determine the mandatory metering provisions for both primary and secondary services.

The Contractor is responsible for meter and service applications and must coordinate with the Owner during the application and energization process. The cost of the electrical service and the ongoing operating costs are borne by the Owner unless directed otherwise by the Engineer.

At each utility metering point, communications must be provided to the meter to allow for remote metering by the utility provider. Any outside metering must be installed in a stainless steel weatherproof enclosure complete with a Lexan viewing window.

To avoid unnecessary delays, detailed plans of panelboards or cubicles must be submitted for acceptance as early as possible in design to allow the utility service provider to order any equipment necessary to complete the metering arrangements. The utility service provider may request that the Contractor supply the digital meter. In this case the Designer must obtain the meter specifications for inclusion in the Contract Documents.

11.9.2 Distribution Equipment Metering

Owner distribution equipment metering is required for system load management and analysis. The placement of distribution equipment metering must be developed with the Engineer and Operator to provide a benefit to planned maintenance, system outage response, and future expansion. At minimum, a meter is required at an input of the normal utility feed. Appendix 11A Figure 11.2 identifies these metering points. Refer to the City of Edmonton's Facility Consultant Manual – Volume 2 for more details on metering and power metering requirements.

Metering must be SEL-735 Advanced for the main client meter and SEL-735 Basic for all other locations. The metering devices must be capable of connection to the communication network, be remotely monitored, and permit integration with BMS. The Designer must coordinate the metering device communication protocol with the Engineer and Operator to ensure applicability of the device to the LRT communications network. This may also include all utility service provider metering systems. The Designer must confirm the need for revenue metering to be interfaced with the BMS.

Owner metering located along the LRT ROW or in the Street environment must be installed in a stainless steel weatherproof enclosure complete with a Lexan viewing window. Where practicable, the distribution meters should be powered from backup power allowing the meters to remain active during a power outage.

11.10 GROUNDING AND BONDING

Grounding and bonding must be provided for all metallic structures, buildings, cases, and systems equipment to provide a safe and reliable system. When designing the grounding and bonding on the LRT System, the Designer must consider equipotential planes, protective device return paths, electrical noise, reference points for electrical equipment, and lightning and surge protection. The grounding system must be capable of supporting the anticipated fault levels from all sources. The materials used must be suitable for the environment they are installed in.

For projects impacting the operating LRT System, the existing grounding must be reviewed and noted while evaluating the feasibility of installing the necessary grounding to align with these requirements. Project budget and system infrastructure constraints should be evaluated for potential upgrades to existing LRT grounding systems where practicable.

All metallic structures, buildings, cases, and systems equipment within 2 m of the OCS/TP structures must be bonded to the OCS ground to ensure an equipotential plane. This includes all exposed conduits and raceways. Only systems negatively impacted by bonding to the OCS system may be exempt from this requirement, and if so the Designer must reduce or eliminate the possibility of both grounding systems being contacted by an individual at the same time.

11.10.1 General

11.10.1.1 Grounding Electrodes and Conductors

At required locations, a combination of CSA certified ground electrodes and conductors must be designed and installed to create a low impedance connection to ground. The size and rating of the ground electrodes and conductors must be designed to meet site-specific fault and surge requirements.

11.10.1.2 Connections

Above-grade grounding and bonding connections may be made with mechanical or compression connections. Below-grade ground electrode and grid cable connections must be made with compression type connectors installed with a suitable hydraulic press. Exothermic welding may be permitted only where no other connection types are practicable. Bolted/mechanical connections must be used where separation of ground elements is required for testing.

11.10.1.3 Inspection Wells

A CSA certified inspection well is required where access to ground conductors below grade is necessary for testing. The wells must be strategically placed to avoid damage and must be rated for the location of the well.

11.10.1.4 Ground Bus

All electrical, communication, and Signal equipment rooms must be provided with a copper ground bus connected to the local ground grid for equipment to be bonded to ground. These ground connections must be extended to the communications cabinets and Signal equipment cases in their respective rooms.

The size and number of ground bus may vary depending on the type of equipment being protected.

11.10.1.5 Theft Prevention

Where practicable, grounding and bonding conductors must be concealed and/or mechanically protected to prevent copper theft. Where ground conductors are exposed, the Designer must employ methods that discourage theft and facilitate replacement of the copper by the Operator.

11.10.1.6 Transformer Grounding

As per CEC, a grounding conductor must be run from the supply distribution centre to the neutral on the secondary of a transformer and to the system grounding bus.

11.10.1.7 Transfer Switch Neutral and Grounding

All transfer switch neutral and grounding connections must meet CEC, providing a safe return to the transformer and proper isolation of deenergized circuits.

11.10.2 Right-of-Way and Traction Power Grounding (Tunnels or Grade Separations)

Separate grounding systems are required in tunnels and portals for TP and LRT ROW grounding.

11.10.2.1 Right-of-Way Grounding

The LRT ROW grounding system must consist of two continuous copper conductors (ground runners), one per track. The LRT ROW ground runner must run the entire length of a tunnel 1 m above the top of the track. The LRT ROW ground runners must be terminated to dedicated ground grids at each end of the tunnel. Cross tie conductors bonding the two runners must be provided every 400 m.

All miscellaneous metallic objects located in the tunnel sections that are not associated with the Traction Power System (TPS) must be bonded to the ROW ground runners. These include ladders, doors, grates, lights, hand and guardrails, junction boxes, control cabinets, conduits, fire line piping, and any miscellaneous metal brackets.

All continuous miscellaneous metal must be bonded at 50 m intervals and connected to the LRT ROW, depending on the distance between the metal and the grounding system. Unless determined otherwise, the pigtails connecting all miscellaneous metals to the ground runner must be sized as per CEC.

Tunnel and portal rebar must be bonded by pigtails secured to the rebar with approved grounding clamps and brought through the tunnel liner formwork for termination. Tunnel liner rebar must be bonded at 50 m intervals. The bonding of the rebar must follow the recommendations of the Stray Current Mitigation Plan. Refer to Chapter 13, Corrosion and Stray Current.

11.10.2.2 Traction Power Grounding

For TP grounding, an appropriately sized copper grounding conductor must be installed in the tunnel for each track. The size and rating of the ground conductors must be designed to meet all applicable codes as well as the site-specific fault and surge requirements.

The OCS grounding conductors must be surface mounted under the tunnel ceiling, run the entire length of the tunnel, and be interconnected to all the OCS supports and switches in the tunnel. The OCS grounding conductors must be terminated to dedicated ground grids at each end of the tunnel.

All miscellaneous TP metallic objects located in the tunnel sections must be bonded to the TP ground conductor. These include OCS structures, protective shields, OCS assembly brackets, and switch enclosures. All miscellaneous metallic objects within 2 m of the catenary overhead support must be bonded to the catenary grounding system.

11.10.3 Right-of-Way and Traction Power Grounding (Open or Trenched Trackway)

Separate grounding systems are required for TP and LRT ROW grounding.

11.10.3.1 Right-of-Way Grounding

The typical open Trackway LRT ROW grounding system consists of two continuous stranded copper conductors (ground runners) that run parallel to the tracks for bonding various equipment and metallic structures to ground. These ground runners are typically installed below the track ballast or Trackway structure and routed alongside or above the track drainage system. The ground runners must be connected to ground grids at each Station. Cross tie conductors must be provided between the two runners at a minimum of 400 m intervals. To reduce fault current magnitudes in the event of a downed OCS cable, the ground runners must be strategically segmented where practicable.

The ground runners are not required to be tied to any concrete reinforcing steel unless it is deemed necessary through the Stray Current Mitigation Plan (see Chapter 13, Corrosion and Stray Current). All connections must be made using compression connectors. Ground/bond conductors are not required within the concrete of duct banks.

11.10.3.2 Traction Power Grounding

For TP OCS poles with no positive feeders or boosters, only one localized ground grid per pole base is required. For poles with feeders or boosters, a second dedicated ground grid for lightning protection grounding must be provided. The two ground grids must be separated by at least 2 m and be bonded together. Lighting protection grounding must also be provided at portal entrances, elevated Grade Separation structures, and midway between TPSS locations. Lightning protection grounding must be coordinated with the OCS Designer.

All miscellaneous metallic objects within 2 m of an OCS pole or structures must be connected to the OCS ground grid.

11.10.4 Ground Fault Protection

Ground fault protection must be provided on all major feeders if required by code or as determined by the Designer. The Designer must evaluate the risk of devices being exposed to moisture and water based on their location and potential impacts to the system to determine if additional ground fault protection is required. The Design must include proper coordination between downstream overcurrent devices and upstream ground fault protected breakers. Coordination of all electrical overcurrent devices must be undertaken in accordance with IEEE 242-2001 [212].

11.10.5 Stray Current

The Designer must recognize the potential for Stray Current and the need for protective systems. The electrical systems Designer must refer to the Stray Current Mitigation Plan and implement the recommendations therein to minimize and mitigate Stray Current corrosion. Refer to Chapter 13, Corrosion and Stray Current for specific design guidelines.

11.11 DUCT BANKS AND RACEWAYS

Duct banks and raceways provide a common, coordinated, protected electrical routing for the cable interconnections required for and associated with the operation and control of the LRT System.

Typically, four duct bank systems must be provided:

- Communications and Signals
- TP
- LRT ROW electrical
- Utility power

Duct banks are constructed within the LRT ROW, generally alongside the Trackway, with cable vaults or pullboxes provided along the length of the duct bank.

11.11.1 Duct Bank Construction General Requirements

11.11.1.1 Duct Bank Construction

Underground duct banks must be constructed of concrete encased conduit type DB2 or equivalent and reinforced with steel rebar. Conduits must be spaced in accordance with the manufacturer's recommendations. Duct spacers must be provided to maintain even spacing of ducts.

The main reinforcing steel must be 15M and placed so that the lengths overlap a minimum of 300 mm. The placement of the rebar must be designed to reinforce the concrete structure, particularly at the bottom of the duct bank.

A minimum of 50 mm of concrete cover must be provided for direct burial installations, and should be 75 mm where practicable. Depending upon the location, additional reinforcing may be required to accommodate structural loads. This requirement must be coordinated with the structural Designer. Concrete strength must be a minimum of 20 MPa at 28 days. Type 50 (HS) Sulphate Resistant cement must be used if recommended in the geotechnical report.

Bell ends must be provided at vaults, pullboxes, and trenches. Duct plugs must be installed on all empty ducts. Vertical ducts entering a building, case or enclosure must be sealed.

For utility ducts that will be installed by the Contractor in the LRT ROW, the Designer must refer to the utility provider's customer connection guidelines for additional requirements.

11.11.1.2 Depth and Clearances

An average cover depth of 650 mm below grade or sub-ballast must be provided for LRT duct bank installations to prevent damage due to load and to avoid influencing track performance when crossing or near the Trackway. This depth may vary based on field conditions. The duct systems must be encased in concrete.

The minimum allowable clearance distance from the centreline of a duct bank to the centreline of track is 3.0 m, to permit safe access to vaults. This clearance may vary based on routing constraints such as available property and other design elements in the LRT ROW. Coordination must occur with interfacing Designers and the Engineer to determine the routing of each duct bank.

11.11.1.3 Cable Vaults and Pullboxes

Concrete cable vaults and pullboxes are required for cable pulling and must be installed at specified intervals along the duct bank. Vaults and pullboxes vary in size and load capacity depending on the application and site-specific conditions. The vaults and pullboxes must have sloped floors and dedicated drainage openings for connection to the LRT ROW drainage system. Cable pulling eyes must be provided at all pullboxes and vaults.

The cable vault covers and their associated frames must be cast iron. Pullbox lids must be lightweight high impact aluminum. Vaults may require slam-lock lids and 90º hold open arms.

Identification labels must be provided on pullbox lids as well as the duct assignment inside the pullbox. Refer to Appendix 11A Figure 11.7 for typical pullbox details. The Designer must provide an identification schedule for both conduit and cable for review and acceptance by the Engineer.

Cable vaults and pullboxes must be sized to accommodate any required cable routing, racking, management, and organization including any proposed cable coils used to achieve spare cable length. The Designer must maximize the efficiency of cable management within a pullbox or vault by having cables neatly racked and by considering entry and exit cable routing when assigning conduits.

11.11.1.4 Drainage

All duct banks must be gravity-drained towards cable vaults and pull-boxes. Sags in a duct bank run are not permitted, and a minimum slope of 1:250 is required to provide adequate flow. Refer to Chapter 16, Utilities and Drainage.

All cable vaults and pullboxes must be connected to a functioning drainage system and incorporate backflow prevention. For brown-field duct bank installations, the Designer must investigate the possibility of connecting into a local drainage system. A dry well system may be considered only if connection to a gravity storm drainage system is not practicable. Dry well applications must be approved by the Engineer.

Where cable vaults and pullboxes are in tunnels or cannot be drained by gravity, water level detection and sump pumps must be installed. Refer to Chapter 12, Mechanical for BMS monitoring of these devices.

11.11.1.5 Branch Ducts

Concrete encased branch ducts for stub points and branch lines should be constructed with the main duct system where practicable. All conduits crossing Streets must be encased in concrete and placed a minimum of 300 mm below subgrade elevation. The Designer must confirm that all duct crossings are at a depth that will not impact the performance of the Street infrastructure or the track support system.

11.11.1.6 Cable Pulling

The pulling tension recommended by the cable manufacturer must not be exceeded when pulling cables. Duct banks and branch ducts must be designed based on the intended cable installation. The number of bends must be minimized to reduce cable pulling tension and the distance between pull points must be adjusted based on the number of bends included in the Design. The minimum radius of any bends must be 900 mm.

11.11.1.7 Identification of Ducts, Cable Vaults and Pullboxes

The identification of ducts, cable vaults, and pullboxes must be system specific and follow the existing standard developed by the Operator. Schedule lists for all ducts, cable vaults, and pullboxes must be developed as part of the Design for review by the Engineer.

11.11.1.8 Separation

If practicable, or as required by specific standards or codes, the four duct bank systems must be kept separate. Separation distances of the concrete encased duct banks must meet specific standards and code requirements. Routing and placement must follow good engineering practice.

11.11.1.9 Warning Tape

Heavy-gauge, yellow, plastic, direct burial warning tape must be installed over all duct banks and branch ducts. The tape must be made of material resistant to corrosive soil. Tape must have a printed warning that an electric circuit is located below the tape.

11.11.1.10 Tracer Wire

Tracer wires must be installed as part of the duct bank construction with the ends of the wires terminated and labeled in the associated pullboxes and cable vaults.

11.11.2 Communications & Signals

A main duct bank and a network of branch ducts are required for the connection of cables between Signal and communications rooms, bungalows, and cabinets to field devices along the LRT ROW. The duct bank Designer must coordinate with the Signal and Communications Designers to confirm the number, size, and routing of the Signal and Communications ducts. The following are the specific requirements for the communications and Signal duct bank and branch ducts:

- The minimum configuration of the main communications and Signals duct bank must be 12 x 103 mm ducts (refer to Appendix 11A Figure 11.1)
- The maximum straight line spacing between vaults and pullboxes must be 200 m
- A maximum of 180º of bends is permitted between pullboxes with 90º bends considered to be communications sweeps with a radius of 11x the overall diameter of the duct
- 103 mm branch ducts must be run from the nearest vault or box to the field device
- Spare ducts must be run to all bungalows and Signal rooms and include pull cords for future cable installation.
- The need for additional spare ducts to field devices must be determined by the Designer
- Where required, typically in conduit routes not using the full allowable fill or in large conduits housing multiple cable types and systems, inner ducts must be installed to facilitate future cable installation
- Dedicated cable vaults and pullboxes must be provided for Signals and for communications

11.11.3 Traction Power

Positive and negative TP ducts distribute power cables from a TPSS to the OCS and rails. The duct bank Designer must coordinate with the Traction Power Designer to confirm the number, size, and routing of the traction power ducts. The following are the specific requirements for the TP duct bank and branch ducts:

- All TP ducts must be 103 mm DB2 PVC, concrete encased, and sloped towards pullboxes or cable vaults for drainage
- Pullboxes and/or manholes must be installed as required with a maximum straight line spacing of 120 m
- Catenary power ducts, vaults, and pullboxes must be sized to take a maximum 1000 kcmil cable
- Each duct run must not exceed a maximum equivalent of three 90º bends
- Ducts must be routed with a preferred 3.0 m clearance from the centreline of the tracks
- All TP ducts crossing the Trackway must cross at 90º
- One spare duct must be provided for each positive feeder circuit
- Two spare ducts must be provided for each negative circuit
- All 90º bends must have a minimum bending radius of 900 mm
- Dedicated cable vaults and pullboxes must be provided for TP and must not be routed within 1.5 m of the centre of track when run parallel the LRT Trackway

11.11.4 Right-of-Way Electrical

Duct banks and branch ducts are required to house cables providing electrical power to the devices located along the ROW including, but not limited to:

- Power distribution cabinets
- Marshalling cabinets
- Signal bungalows and/or Signal cases
  - Switch blowers
- Switch machines
- Rail lubricators

The following are the specific requirements for the LRT ROW electrical duct bank and branch ducts:

- For Mainline duct banks, 2 x 103 mm or 4 x 103 mm ducts should be used, subject to load determination (refer to Appendix 11A Figure 11.2)
- The maximum allowable vault/pullbox straight line spacing is 400 m
- Dedicated pullboxes are required for LRT ROW electrical
- For the main LRT ROW electrical duct bank, 25% spare ducts must be provided

11.11.5 Utility Power

For medium and low voltage AC utility power feeders, the Contractor is responsible for all underground infrastructure within the LRT ROW. All conduits must be rigid PVC, DB2, or as required by in the latest version of the utility provider’s customer connection guide. The conductors must be separated from other systems as per applicable codes and standards or the utility provider requirements.

The following are the specific requirements for utility duct banks:

- Utility AC conduits must have a minimum bending radius of 900 mm or as required by the utility service provider
- Utility cables must be installed in a reinforced concrete encased duct bank
- Thin wall PVC (DB2) and/or rigid PVC must be used when encased in concrete
- Sizes of the ducts must be based on the cable size being installed or as required by the utility service provider
- Utility cable vaults and pullboxes must comply with the utility service provider’s standards

11.11.6 Conduits and Raceways Additional Requirements

11.11.6.1 Sealing of Conduit

All conduits entering or leaving a building below grade must be designed to drain away from the building and the equipment contained therein. Channeling the water towards the equipment is not permitted. Alternatively, conduits entering a building may be sealed using a sealing system approved by the Engineer.

11.11.6.2 Fastening Devices

All electrical equipment, conduits, and raceways must be fastened with flush mount internal threaded metallic anchoring systems designed for the specific application. The fastener spacing must be as per CEC. Plastic, wood, or malleable metal inserts and shot driven pins and fasteners for securing electrical conduit or equipment are not permitted.

Multiple conduit runs must be rack mounted on Unistrut or equivalent mounting equipment, with a minimum of 25% spare rack space.

Conduits and raceways must not be fastened to other systems structures unless coordinated between both systems Designers and meeting CEC.

11.11.6.3 Conduits within Tunnels/Stations

All conduit and associated boxes within tunnels and/or Stations on exterior walls must be mounted a minimum of 25 mm from the wall. Nylon spacers are permitted.

11.11.6.4 Fiberglass Conduit

For TP positive and negative cable installations in above- and below-grade applications, corrosion resistant, Reinforced Thermosetting Resin Conduit (RTRC) must be used. The conduit and fittings must be suitable for above ground and bridge applications.

11.11.6.5 Conduit in Slabs

For new installations, conduit should not be placed directly in concrete slabs. If placement in a concrete slab is the only practicable alternative, this application must be reviewed and approved by the Engineer and the Operator.

When required, all conduit located in slabs between levels where coring may be required in the future must be located and dimensioned to a tolerance of ±50 mm on the plan of record drawings.

11.11.6.6 Empty Conduits

Empty conduit systems must be provided for TPS, Signals, communications, antennae, telephone, CCTV, and BMS. Conduits must be swabbed clean and must have an appropriate number of nylon pull cords installed.

11.11.6.7 Raceways

Rigid galvanized steel conduit must be used in all exposed raceway installations and in tunnels.

PVC or DB2 conduit may be used when encased in concrete and PVC conduit must be used when directly buried in soil. PVC conduit emerging from grade or from concrete and routing on the surface must be converted to rigid steel for all non-TP installations. The transition from PVC to rigid steel conduit must be through a coupling that is covered in a heat shrink sleeve and taped. The transition must take place before emerging from soil or from concrete. PVC conduit emerging from grade but routing directly into an enclosure does not require transitioning to rigid steel conduit.

Electrical Metallic Tubing (EMT) conduit must be used as the principal raceway within a TPSS with the exception of the DC TP and the MV power. No plastic pipe may be used within a TPSS. Plastic pipe emerging within the TPSS must be converted to either rigid steel, RTRC, or EMT. Metal conduit must be bonded to ground using the correctly sized bonding cable for protection.

All conduit in raceway installations must be provided with supports not more than 3 m apart. The supports used in raceway installations may be clamps for wall-mounted conduits or trapeze-type racks.

For existing and severe environment areas, the Designer must consult with the Engineer for direction on the possible requirement for stainless steel conduits.

11.11.6.8 Expansion Joints

Conduits that are prone to the effects of expansion and contraction, such as at bridge abutments, must be fitted with expansion joints. Conduits that may experience both horizontal and vertical movement must be provided with deflection fittings. The Design must accommodate all conduits that are routed to or through fixed structures, and which will, due to temperature fluctuations and the seasonal freeze thaw cycles, have different coefficients of expansion and contraction.

11.12 ELECTRICAL UTILITY COORDINATION

The Designer should engage the services and input of the utility service provider early and continuously throughout the project. The utility provider’s engineering services personnel must be contacted by the Designer and Contractor for site-specific planning details and constraints, and to coordinate and schedule the utility provider’s engineering and construction groups.

It is the Designer’s responsibility to coordinate all electrical utility services for the LRT System. Typically, both low and MV utility power is required by the LRT System. The utility service providers may have specific requirements that must be met during Design and construction. It is the Designer’s and Contractor’s responsibility to obtain the necessary acceptance for both the Design and the installation of utility infrastructure as well as the equipment that interfaces with the utility. Based on the project requirements, a primary and/or secondary metered service may be required. For specific details on the design and construction requirements refer to the latest version of the utility provider’s customer connection guide.

11.13 TESTING AND COMMISSIONING

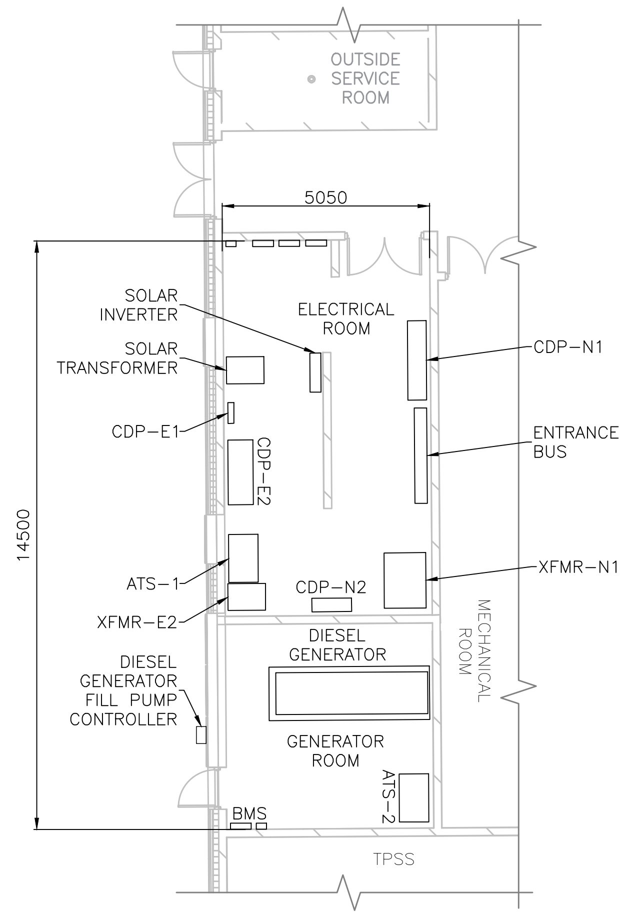
Testing and commissioning must be carried out in accordance with the overall commissioning plan and program which can be found in Chapter 1, General.

11.14 STANDARD RECORD DOCUMENTS

For standard record documentation requirements refer to Chapter 1, General.

APPENDIX 11A – FIGURES

CITY OF EDMONTON LRT
DESIGN GUIDELINES



NOTES:

1. ALL DIMENSIONS ARE APPROXIMATE AND ARE SHOWN IN mm.
2. UTILITY PROVIDER PAD MOUNT STATION SERVICES TRANSFORMER IS LOCATED IN UTILITY COMPLEX YARD.
3. 600 VAC AND 120/208 VAC EQUIPMENT ARRANGEMENT IS TYPICAL AND DEPENDENT ON SYSTEM SPECIFIC LOADING REQUIREMENTS AND TYPE.
4. DOORS TO BE SIZED TO ALLOW TRANSFORMERS AND NECESSARY EQUIPMENT TO PASS THROUGH.
5. SECONDARY STATION SERVICES TRANSFORMER LOCATED IN TPSS ROOM.
6. PERMANENT STANDBY GENERATOR ROOM ONLY REQUIRED ON A LOCATION SPECIFIC BASIS. REQUIREMENT TO BE COORDINATED DURING DESIGN.

Date	Revision	FIGURE 11.1 TYPICAL UTILITY COMPLEX ELECTRICAL ROOM EQUIPMENT LAYOUT	CHAPTER 11 ELECTRICAL

CITY OF EDMONTON LRT
DESIGN GUIDELINES

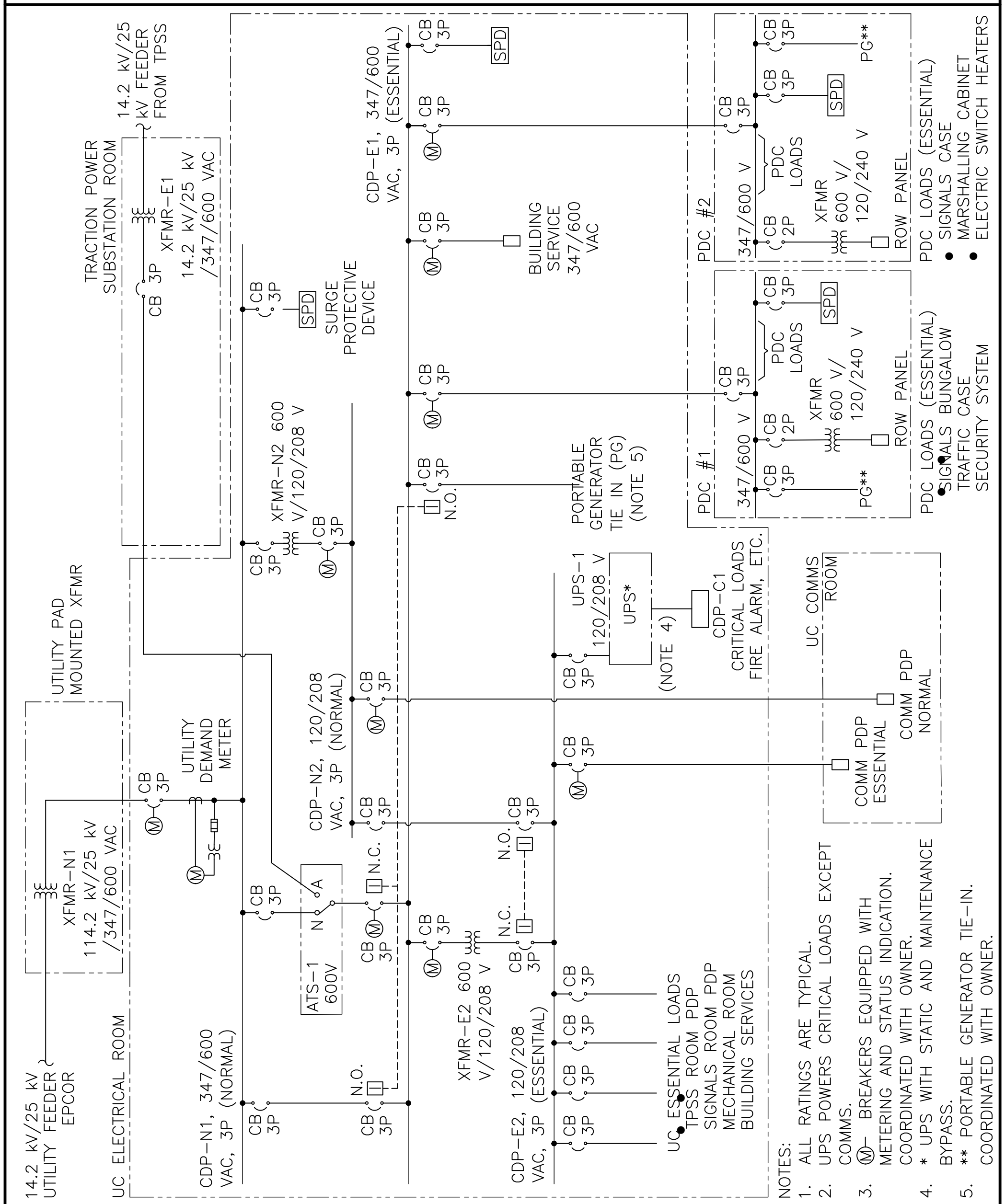
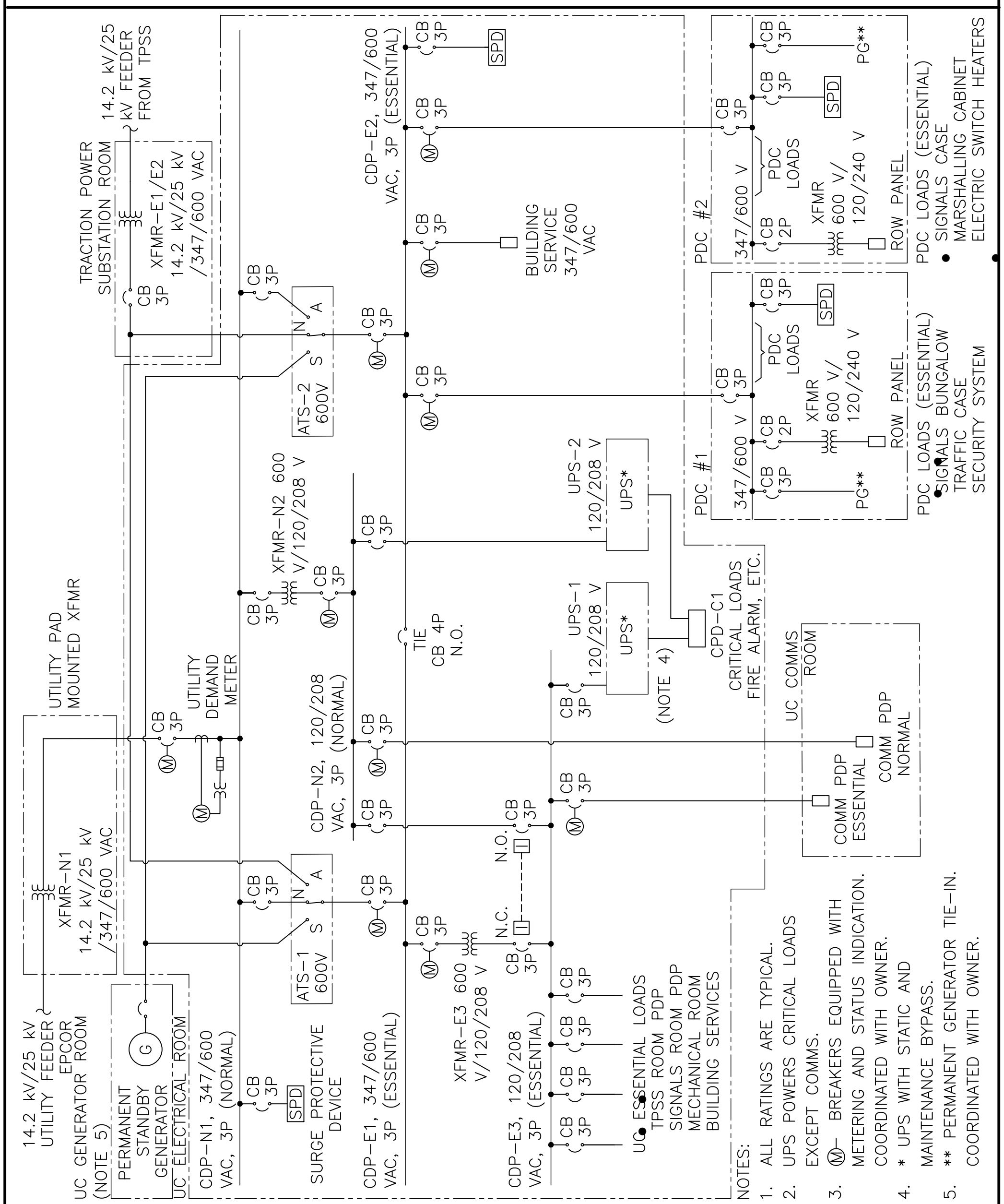


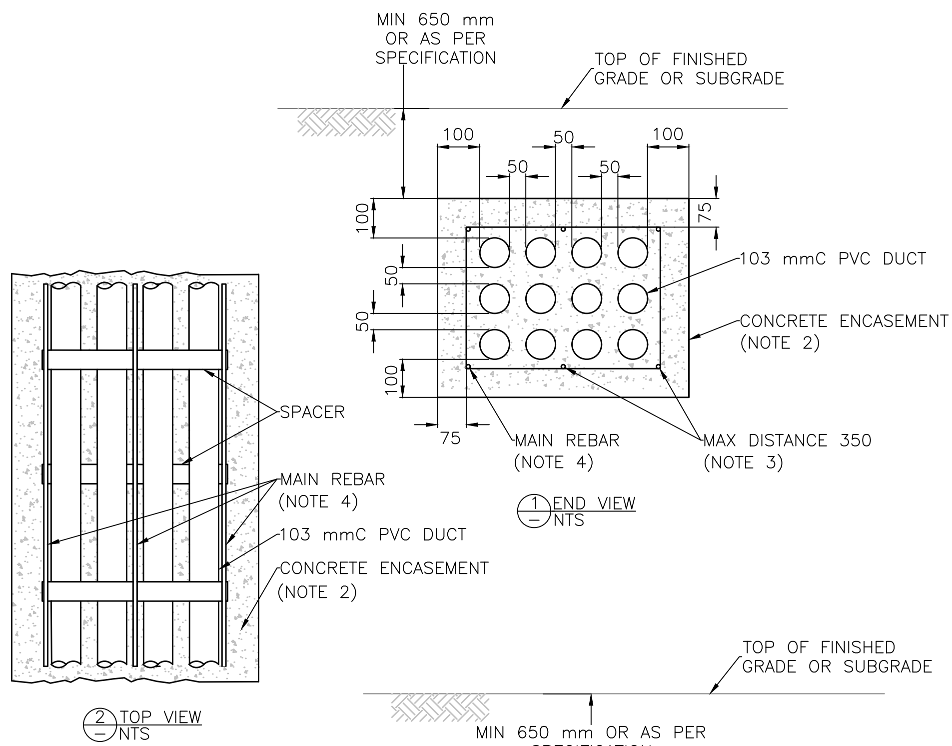
		FIGURE 11.2	CHAPTER 11
		TYPICAL ELECTRICAL ROOM SINGLE LINE DIAGRAM	ELECTRICAL
Date	Revision		

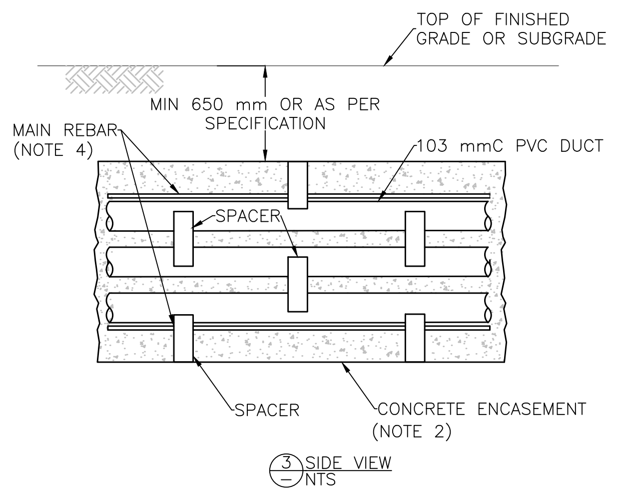
CITY OF EDMONTON LRT
DESIGN GUIDELINES



Date	Revision	FIGURE 11.3	CHAPTER 11
		TYPICAL ELECTRICAL ROOM SINGLE LINE DIAGRAM WITH DATA CENTRE	ELECTRICAL

CITY OF EDMONTON LRT
DESIGN GUIDELINES



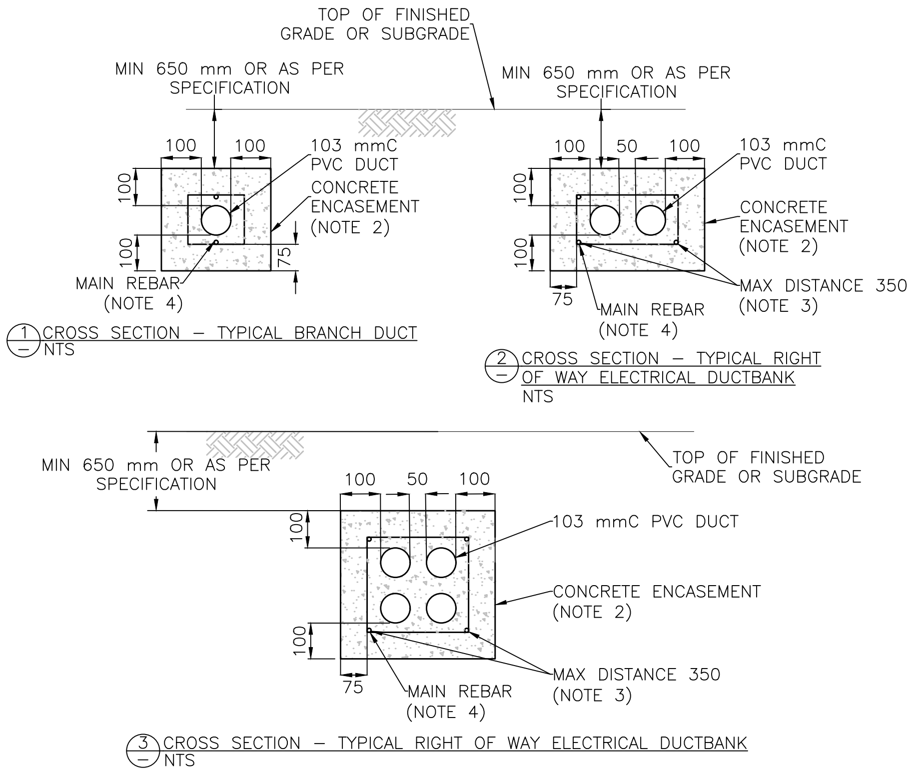


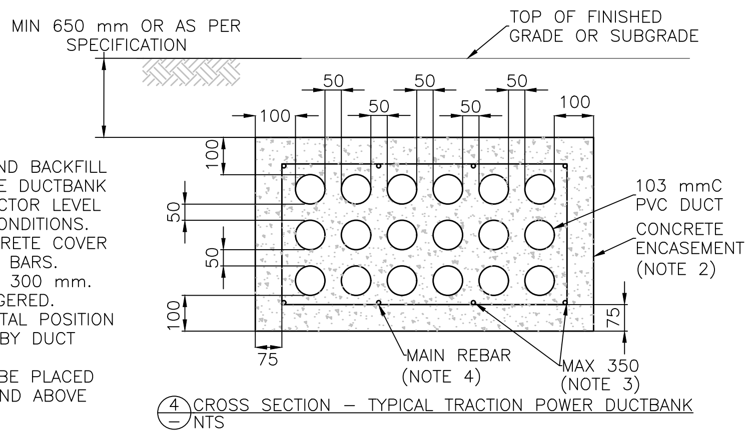
NOTES:

1. THE GROUND BELOW AND BACKFILL ON BOTH SIDES OF THE DUCTBANK IS COMPACTED TO PROCTOR LEVEL DEPENDENT ON SOIL CONDITIONS.
2. 75 mm MINIMUM CONCRETE COVER FOR MAIN REINFORCING BARS.
3. REBAR MINIMUM LAP IS 300 mm. REBAR LAPS ARE STAGGERED.
4. VERTICAL AND HORIZONTAL POSITION OF REBAR MAINTAINED BY DUCT SPACERS.
5. DUCT SPACERS SHALL BE PLACED BELOW, IN–BETWEEN AND ABOVE DUCTS.

		FIGURE 11.4	CHAPTER 11
		TYPICAL COMMUNICATION DUCTBANK CONFIGURATION	ELECTRICAL
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES





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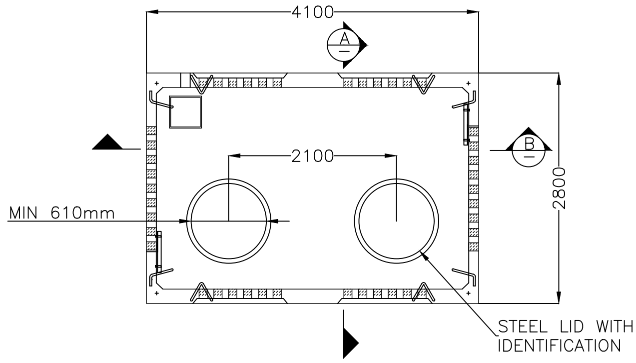
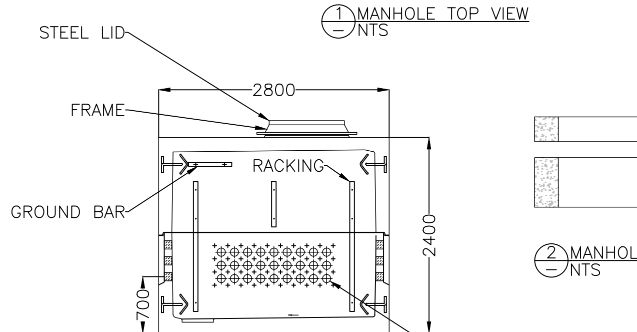
4. VERTICAL AND HORIZONTAL POSITION OF REBAR MAINTAINED BY DUCT SPACERS.
5. DUCT SPACERS SHALL BE PLACED BELOW, IN–BETWEEN, AND ABOVE DUCTS.

Date	Revision	FIGURE 11.5	CHAPTER 11
		TYPICAL RIGHT OF WAY ELECTRICAL AND TRACTION POWER DUCTBANK CONFIGURATION	ELECTRICAL

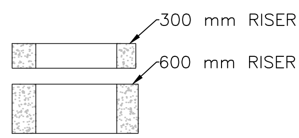
CITY OF EDMONTON LRT
DESIGN GUIDELINES



1 MANHOLE TOP VIEW
NTS



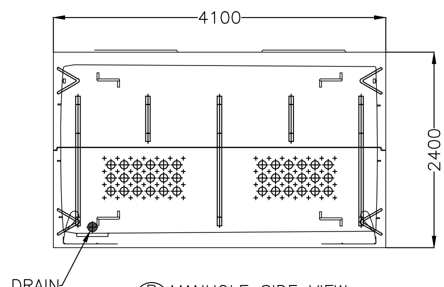
A MANHOLE END VIEW
NTS



2 MANHOLE RISERS SIDE VIEW
NTS

NOTES:

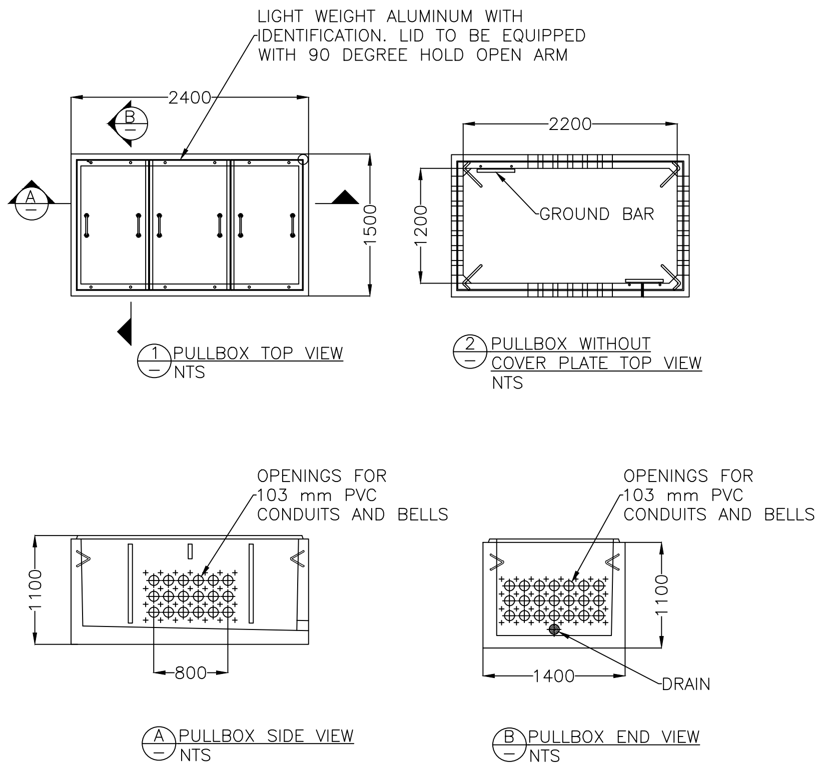
1. DIMENSIONS ARE APPROXIMATE AND ARE SHOWN IN mm
2. ALL MANHOLES TO BE EQUIPPED WITH A GROUND BAR THAT IS CONNECTED TO A DEDICATED GROUND GRID WITH A MAXIMUM OF 10 OHM RESISTANCE TO EARTH.
3. ALL MANHOLES TO BE CONNECTED TO THE SUBDRAIN SYSTEM AND INCORPORATE BACK FLOW PREVENTERS.
4. MANHOLES IN TUNNELS AND GRADE SEPARATIONS SHALL BE EQUIPPED WITH SUMP PUMPS IF THEY CANNOT BE DRAINED TO A SUB DRAIN SYSTEM.
5. MANHOLES TO BE DESIGNED TO WITHSTAND EQUIPMENT WEIGHTS WHERE NECESSARY.



B MANHOLE SIDE VIEW
NTS

		FIGURE 11.6	CHAPTER 11
		TYPICAL MANHOLE DETAILS	ELECTRICAL
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES



NOTES:

1. DIMENSIONS ARE APPROXIMATE AND ARE SHOWN IN mm
2. ALL PULLBOXES TO BE EQUIPPED WITH A GROUND BAR THAT IS CONNECTED TO A DEDICATED GROUND GRID THAT HAS A MAXIMUM OF 10 OHM RESISTANCE TO EARTH.
3. ALL PULLBOXES TO BE CONNECTED TO THE SUBDRAIN SYSTEM AND INCORPORATE BACK FLOW PREVENTERS.
4. PULLBOXES TO BE DESIGNED TO WITHSTAND EQUIPMENT WEIGHTS WHERE NECESSARY.
5. PULLBOX LID HANDLES SHALL BE RECESSED AND FLUSH WITH PULLBOX LID.

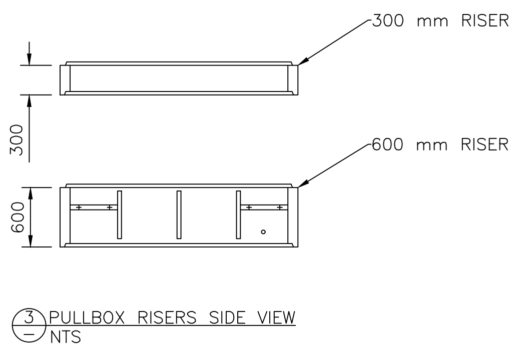
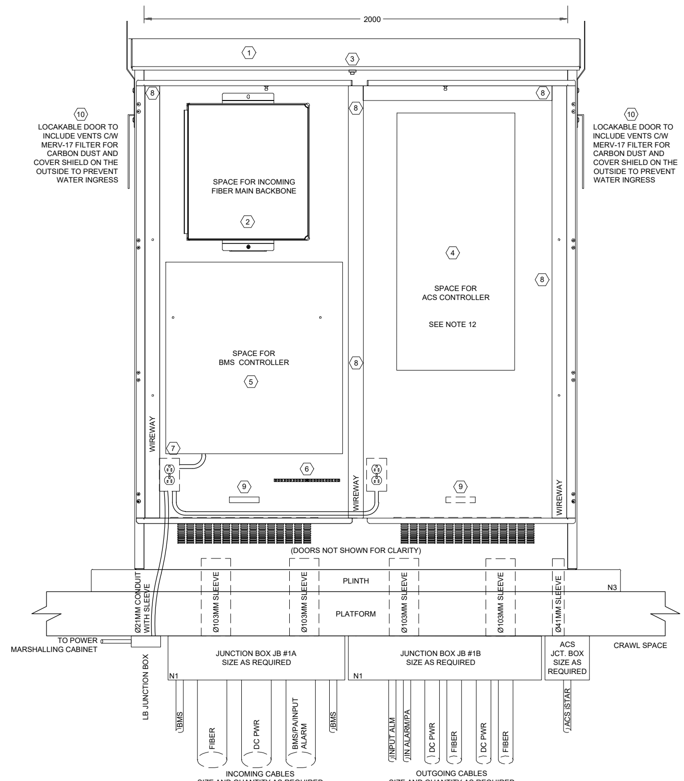


		FIGURE 11.7	CHAPTER 11
		TYPICAL PULLBOX DETAILS	ELECTRICAL
Date	Revision		

CITY OF EDMONTON
LRT DESIGN GUIDELINES



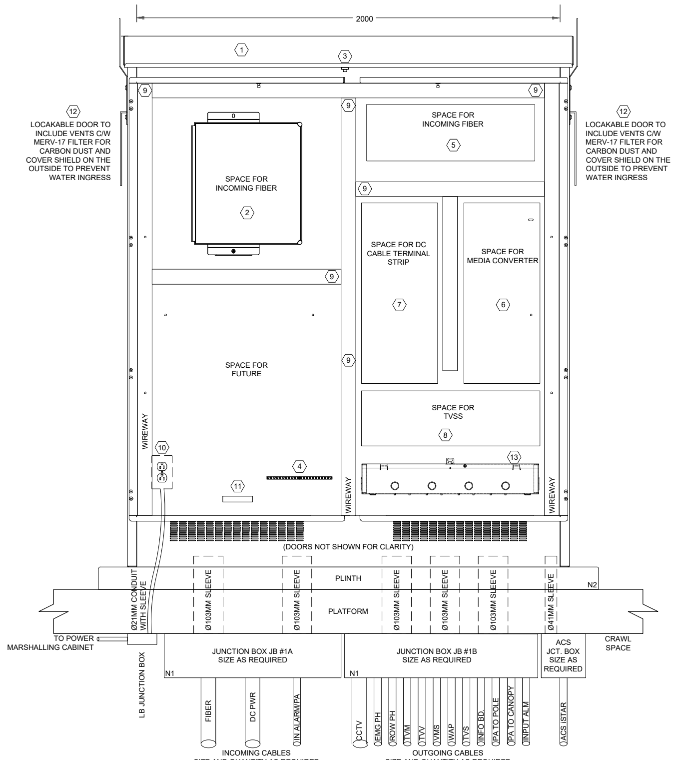
BILL OF MATERIALS	
NO.	DESCRIPTION
1	MARSHALLING CABINET W/ LAMACOID NAME PLATE (SIZE AS REQUIRED) STAINLESS STEEL NEMA 3Rx ENCLOSURE BUILT TO NEMA 4X STANDARDS REFER TO ELECTRICAL DESIGN DRAWINGS.
2	SPACE FOR INCOMING FIBER MAIN BACKBONE
3	DOOR POSITION SENSOR 59150-010/59150-000 LITTELFUSE MAGNETIC REED SWITCH MAGNET SPST-NO WIRE LEADS FLANGE MOUNT AND SWITCH REPLACEMENT MAGNET
4	SPACE FOR ACS CONTROLLER
5	SPACE FOR BMS CONTROLLER
6	ILSCO, GROUND BAR 8 TAPS
7	AC POWER RECEPTACLE
8	WIREWAY PANDUIT F2X4WH6 TYPE F NARROW SLOT WIRING DUCT HAS A NOMINAL DUCT SIZE OF 2W x 4H (50.8mm x 101.6mm) COMPLETE WITH C2WH6 DUCT COVER
9	STRIP HEATER C/W THERMAL SENSOR LOGIC
10	INCLUDE VENTS ON THIS SIDE OF CABINET C/W MERV-17 FILTER FOR CARBON DUST AND COVER SHIELD ON THE OUTSIDE TO PREVENT WATER INGRESS

NOTES:

1. THIS IS A GENERAL ARRANGEMENT FOR A TYPICAL MARSHALLING CABINET. THE ARRANGEMENT AND SIZE CAN VARY FOR EACH LOCATION.
2. RECEPTACLE, CONDUITS & JUNCTION BOXES PROVISIONING BY DIVISION 26.
3. CONNECTION FOR STRIP HEATERS. STRIP HEATER TO OPERATE ON SETPOINTS ON INTERNALLY PLACED THERMAL SENSOR.
4. 316 STAINLESS STEEL NEMA 3RX ENCLOSURE BUILT TO NEMA 4X STANDARDS
5. STEEL WELDED CONSTRUCTION SPECIFICALLY DESIGNED AS RAIN TIGHT
6. 3 POINT STAINLESS STEEL, PAD LOCKABLE HANDLE, HIDDEN HINGE AND 103MM LOW SNOW KICK PER SIDE. EACH DOOR TO BE INDEPENDENTLY LOCKABLE FOR THIS MC ONLY.
7. 53MM FRONT OVERHANGING DRIPHOOD, CROSS BRAKE ROOF, SOFT MACHINE FORMED CORNERS AND LIFTING EYES.
8. WITH CENTER BARRIER
9. INSULATION PACKAGE
10. REFER TO ARCHITECTURAL ABND STRUCTURAL FOR HOUSEKEEPING PAD DETAILS AND CONCRETE FINISH
11. CONDUITS FOR BMS CONTROL CIRCUITS TO BE COORDINATED WITH BMS CONTRACTOR AND PROVIDE AS REQUIRED.
12. ACCESS CONTROL SYSTEM PROVISIONING BY DIVISION 28. REFER TO ELECTRICAL VOLUME I FOR ACCESS CONTROL SYSTEM DETAILS

Date	Revision	FIGURE 11.8a MASTER LOW TENSION MARSHALLING CABINET DETAIL	CHAPTER 11 ELECTRICAL SYSTEMS

CITY OF EDMONTON
LRT DESIGN GUIDELINES



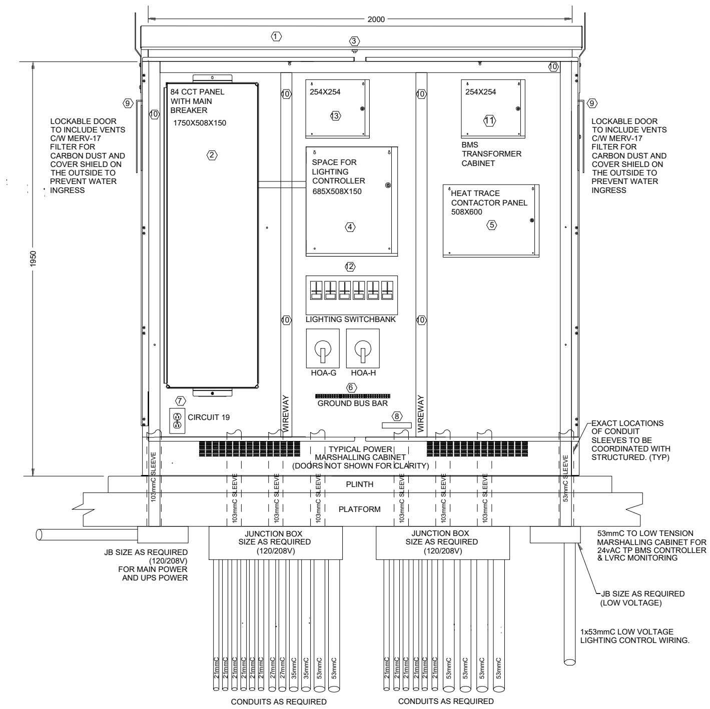
BILL OF MATERIALS	
NO.	DESCRIPTION
1	MARSHALLING CABINET W/ LAMACOID NAME PLATE SIZE AS REQUIRES STAINLESS STEEL NEMA 3Rx ENCLOSURE BUILT TO NEMA 4X STANDARDS REFER TO ELECTRICAL DESIGN DRAWINGS.
2	SPACE FOR INCOMING FIBER
3	DOOR POSITION SENSOR 59150-010/59150-000 LITTELFUSE MAGNETIC REED SWITCH MAGNET SPST-NO WIRE LEADS FLANGE MOUNT AND SWITCH REPLACEMENT MAGNET
4	ILSCO, GROUND BAR 8 TAPS
5	SPACE FOR CAT6 MEDIA CONVERTERS
6	SPACE FOR MEDIA CONVERTERS
7	SPACE FOR DC CABLE TERMINAL STRIP
8	SPACE FOR TVSS
9	F2X4WH6 PANDUIT WIREWAY TYPE F NARROW SLOT WIRING DUCT HAS A NOMINAL DUCT SIZE OF 2W x 4H (50.8mm x 101.6mm), COMPLETE WITH C2WH6 DUCT COVER
10	AC POWER RECEPTACLE PROVISIONING BY DIVISION 26
11	STRIP HEATER C/W THERMAL SENSOR LOGIC
12	CABINET SIDE VENTS C/W MERV-17 FILTER FOR CARBON DUST AND COVER SHIELD ON THE OUTSIDE TO PREVENT WATER
13	CST274 HAMMOND MFG. TYPE 1 MILD STEEL SPLITTER TROUGH

NOTES:

1. THIS IS A GENERAL ARRANGEMENT FOR A TYPICAL MARSHALLING CABINET. THE ARRANGEMENT AND SIZE CAN VARY FOR EACH LOCATION.
2. RECEPTACLE, CONDUITS & JUNCTION BOXES PROVISIONING BY DIVISION 26.
3. CONNECTION FOR STRIP HEATERS. STRIP HEATER TO OPERATE ON SETPOINTS ON INTERNALLY PLACED THERMAL SENSOR.
4. 316 STAINLESS STEEL NEMA 3RX ENCLOSURE BUILT TO NEMA 4X STANDARDS
5. STEEL WELDED CONSTRUCTION SPECIFICALLY DESIGNED AS RAIN TIGHT
6. 3 POINT STAINLESS STEEL, PADLOCKABLE HANDLE, HIDDEN HINGE AND 103MM LOW SNOW KICK PER SIDE.
7. 53MM FRONT OVERHANGING DRIPHOOD, CROSS BRAKE ROOF, SOFT MACHINE FORMED CORNERS AND LIFTING EYES.
8. NO CENTER BARRIER
9. INSULATION PACKAGE
10. REFER TO ARCHITECTURAL ABND STRUCTURAL FOR HOUSEKEEPING PAD DETAILS AND CONCRETE FINISH

		FIGURE 11.8b SLAVE LOW TENSION MARSHALLING CABINET DETAIL	CHAPTER 11 ELECTRICAL SYSTEMS
Date	Revision		

CITY OF EDMONTON
LRT DESIGN GUIDELINES



BILL OF MATERIALS		
NO.	QTY.	DESCRIPTION
1	1	MARSHALLING CABINET W/ LAMACOID NAME PLATE 1950x2000x609 STAINLESS STEEL NEMA 3Rx ENCLOSURE BUILT TO NEMA 4X STANDARDS.
2	1	120/208V, 200A, 3P, 4W, 84 CIRCUIT POWER PANEL BOARD WITH MAIN BREAKER IN BARRIERED COMPARTMENT FOR BUS BAR ISOLATION.
3	1	DOOR POSITION SENSOR 59150-010/59150-000 LITTELFUSE MAGNETIC REED SWITCH MAGNET SPST-NO WIRE LEADS FLANGE MOUNT AND SWITCH REPLACEMENT MAGNET
4	1	DELTA LIGHTING CONTROLLER (SIZE AS REQUIRED)
5	1	HEAT TRACE CONTACTOR PANEL HEAT TRACE CIRCUITS TO BE CONTROLLED FOR ON/OFF OPERATION VIA BMS SYSTEM.
6	2	COPPER GROUND BUS BAR WITH DOUBLE LUG CONNECTORS
7		AC POWER RECEPTACLE - SERVICE
8	1	STRIP HEATER C/W THERMAL SENSOR LOGIC
9	2	INCLUDE VENTS ON THIS SIDE OF CABINET C/W MERV-17 FILTER FOR CARBON DUST AND COVER SHIELD ON THE OUTSIDE TO PREVENT WATER.
10	AS REQD.	SPACE FOR WIREWAYS
11	1	BMS TRANSFORMER CABINET. PROVIDE UPS CIRCUIT FROM UTILITY COMPLEX.
12	1	SPACE FOR LIGHTING SWITCH BANK SWITCHES AS REQUIRED FOR PLATFORM LIGHTING HOA SWITCHES AS REQUIRED
13	1	REMOTE BREAKER COMPARTMENT WITH VOLTAGE SENSING UNIT.

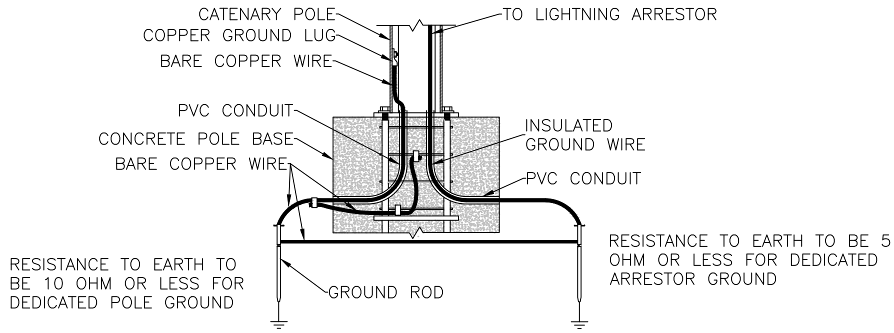
NOTES:

THIS IS A GENERAL ARRANGEMENT FOR A TYPICAL MARSHALLING CABINET. THE ARRANGEMENT AND SIZE CAN VARY FOR EACH LOCATION.

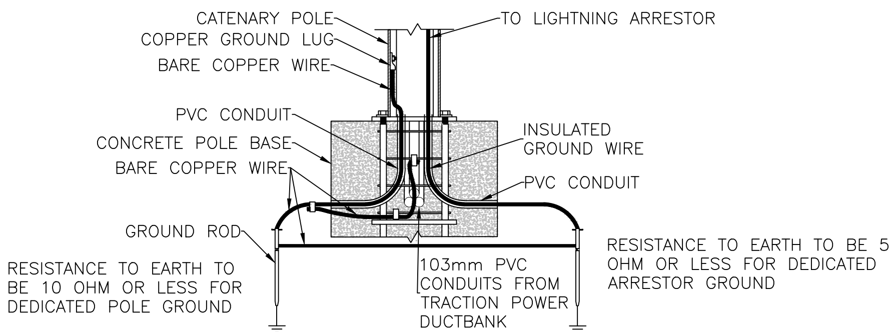
1. RECEPTACLE, CONDUITS & JUNCTION BOXES PROVISIONING BY DIVISION 26.
2. CONNECTION FOR STRIP HEATERS. STRIP HEATER TO OPERATE ON SETPOINTS ON INTERNALLY PLACED THERMAL SENSOR.
3. 316 STAINLESS STEEL NEMA 3RX ENCLOSURE BUILT TO NEMA 4X STANDARDS.
4. STEEL WELDED CONSTRUCTION SPECIFICALLY DESIGNED AS RAIN TIGHT.
5. 3 POINT STAINLESS STEEL, PADLOCKABLE HANDLE, HIDDEN HINGE AND 103mm LOW SNOW KICK PER SIDE.
6. 53mm FRONT OVERHANGING DRIPHOOD, CROSS BRAKE ROOF, SOFT MACHINE FORMED CORNERS AND LIFTING EYES.
7. GALVANIZED BACKPANS
8. NO CENTER BARRIER
9. INSULATION PACKAGE
10. REFER TO ARCHITECTURAL AND STRUCTURAL FOR HOUSEKEEPING PAS DETAIL AND CONCRETE FINISH.

		FIGURE 11.9	CHAPTER 11
		POWER MARSHALLING CABINET DETAIL	ELECTRICAL SYSTEMS
Date	Revision		

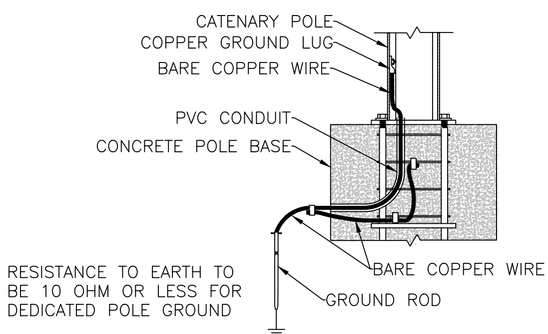
CITY OF EDMONTON LRT
DESIGN GUIDELINES



1 CATENARY POLE WITH LIGHTNING ARESTOR GROUND
NTS



2 FEEDER AND BOOSTER POLE GROUND WITH LIGHTNING ARRESTOR
NTS



3 CATENARY POLE GROUND
NTS

Date	Revision	FIGURE 11.10 TYPICAL CATENARY POLE GROUNDING DETAILS	CHAPTER 11 ELECTRICAL

CITY OF EDMONTON LRT DESIGN GUIDELINES

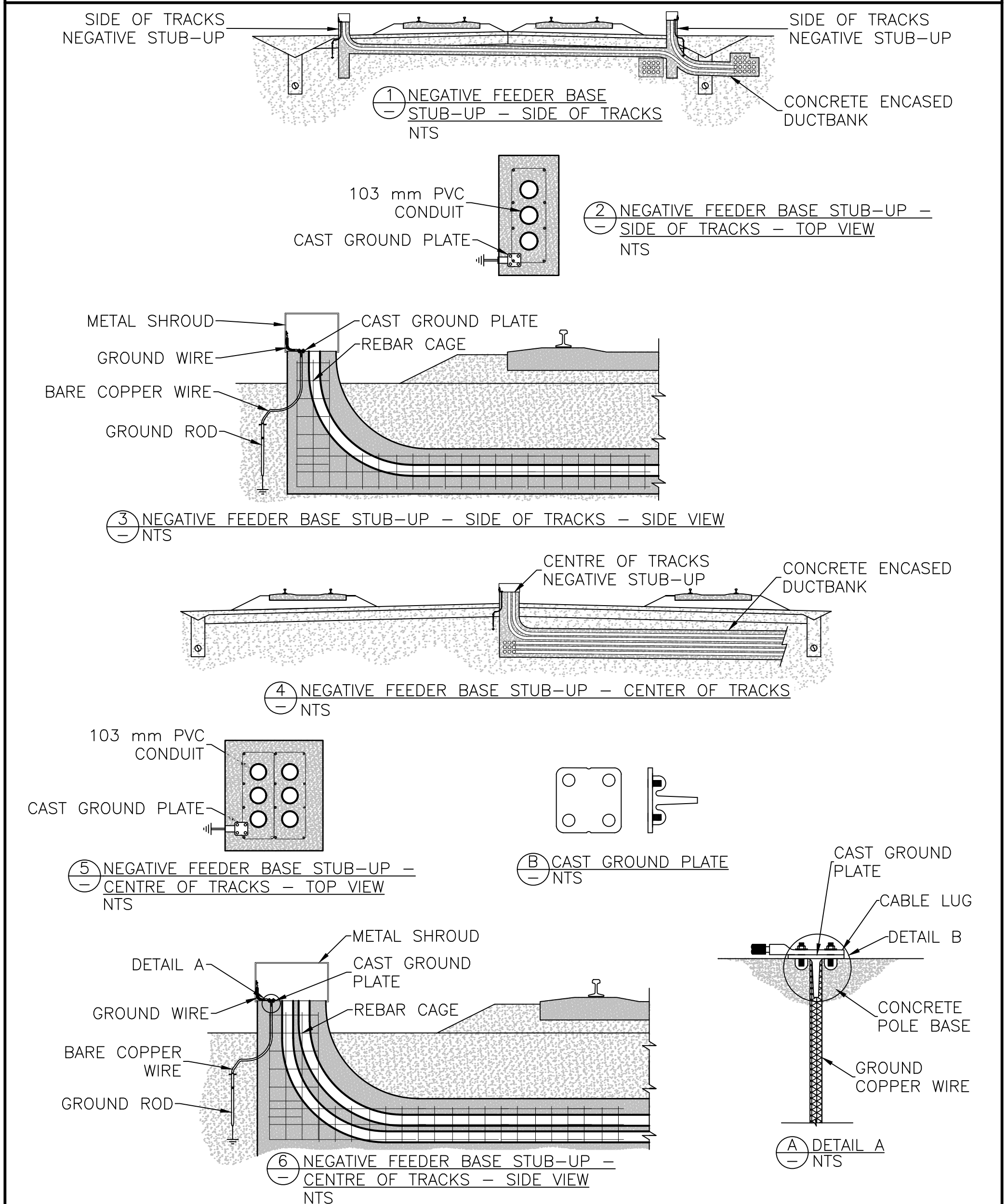


		FIGURE 11.11	CHAPTER 11
		TYPICAL NEGATIVE FEEDER BASE GROUNDING DETAILS	ELECTRICAL
Date	Revision		

CITY OF EDMONTON LRT
DESIGN GUIDELINES

PANEL NAME

DESCRIPTION	KW	BKR			BKR	KW	DESCRIPTION
ELECTRICAL LOAD		15A	1	2	15A		ELECTRICAL LOAD
ELECTRICAL LOAD		20A	3	4	20A		ELECTRICAL LOAD
ELECTRICAL LOAD		XXA	5	6	XXA		ELECTRICAL LOAD
ELECTRICAL LOAD		2P/15A	7, 9	8, 10	2P/15A		ELECTRICAL LOAD
ELECTRICAL LOAD		2P/20A	11, 13	12, 14	2P/20A		ELECTRICAL LOAD
ELECTRICAL LOAD		2P/XXA	15, 17	16, 18	2P/XXA		ELECTRICAL LOAD
ELECTRICAL LOAD		3P/15A	19, 21, 23	20, 22, 24	3P/15A		ELECTRICAL LOAD
ELECTRICAL LOAD		3P/20A	25, 27, 29	26, 28, 30	3P/20A		ELECTRICAL LOAD
ELECTRICAL LOAD		3P/XXA	31, 33, 35	32, 34, 36	3P/XXA		ELECTRICAL LOAD
ELECTRICAL LOAD		3P/XXA	37, 39, 41	38, 40, 42	3P XXA		ELECTRICAL LOAD
TOTAL XXX kW					TOTAL XXX kW		

MAINS:	XXX AMP	VOLTS:	XXX/XXXV
MOUNTING:	SURFACE/RECESSED	PHASE:	3PH, 4W
MAIN BKR:	NONE	LOCATION:	ROOM# XXX
FEEDER:	XXC, X#XXAWG+BOND	FED FROM:	"DEVICE FEEDING PANEL"

ELECTRICAL NOTES:
1. XXX
2. XXX

NOTES:
1. BREAKER RATINGS ARE PROVIDED FOR REFERENCE ONLY. DESIGNER SHALL VERIFY BREAKER SIZES BASED ON REQUIREMENTS OF DESIGN.

Date	Revision	FIGURE 11.12 TYPICAL DISTRIBUTION PANEL LAYOUT	CHAPTER 11 ELECTRICAL

CHAPTER 12
Mechanical

COE-IM-GUIDE-0017 | v02

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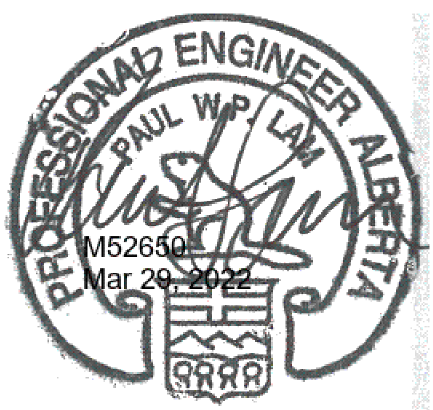
INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

See complete Intent of Use Statement following the cover page.

Professional Engineer Seal



Permit to Practice

PERMIT TO PRACTICE
WSP CANADA INC.

RM SIGNATURE:

RM APEGA ID #: 81684

DATE: MARCH 29, 2022

PERMIT NUMBER: P007641
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

12 MECHANICAL

12.1 INTRODUCTION

This chapter presents guidelines for the Design of the mechanical systems, equipment, and material for Stations and Ancillary Facilities including tunnels.

12.1.1 Applicable Codes, Standards, and Regulations

Unless stated otherwise, the Design must conform to or exceed the requirements of the latest editions of all applicable federal, provincial, and municipal codes and regulations as well as the requirements of the Authority Having Jurisdiction (AHJ). The Designer should be aware of and consider proactive implementation of pending code changes and adoption of new standards.

12.2 GENERAL DESIGN GUIDELINE REQUIREMENTS

12.2.1 Drawing Standards

The following section provides general requirements and the level of detail expected for the Design of mechanical systems. Information on existing system loads, design system performance, and spare capacity for future expansion or modifications to Light Rail Transit (LRT) infrastructure must be clearly identified in the Design. Refer to Chapter 1, General for drawing and document requirements

Each branch and main service of any sanitary, storm, and domestic hot or cold water distribution system must be labelled with the design plumbing fixture load, as per National Plumbing Code (NPC). Each branch and main of any hydronic (heating and cooling) system must be labelled with the design flowrate, and the supply and return water temperature. This information will allow determination of available spare capacity for future renovations.

The Design must provide system schematics indicating the intended overall operation of all mechanical systems. All performance criteria must to be labelled on the schematics.

12.2.2 Specifications

The following section provides general requirements and the required level of detail for project specifications. Detailed information on the performance, quality, and description of equipment, materials, and systems must be included. Detailed sequence of operation and point lists for equipment and systems must be included in the Building Management System (BMS) section of the specifications. Refer to Chapter 1, General, for drawing and document requirements

The Design must provide equipment schedules with performance parameters in the specifications if equipment schedules are not included on mechanical system drawings. The Design must include a description of equipment, material, and systems indicating the performance, quality, and warranty period.

A detailed sequence of operation for all systems complete with points list for all BMS points must also be included.

12.2.3 Load Calculations and Input Parameters

This section provides the requirements for load calculations and input parameters.

The Designer must submit clear and complete load calculations including input parameters and output results. This information must be available for use in future LRT System expansions or modifications.

The Designer must confirm with the Engineer if load calculations from all electrical and mechanical infrastructure should be combined for submission.

A draft load calculation submission must be submitted by the Designer at the 60% review milestone and final submission at the 90% or pre-tender review milestone.

12.2.4 Performance Criteria and Requirements for Mechanical Systems

LRT Stations and Ancillary Facilities have a wide range of specific, individual requirements for heating, cooling, ventilation, plumbing, and fire protection. Refer to the subsections within this chapter for specific system performance criteria and requirements for individual spaces.

12.2.5 Testing and Commissioning

The mechanical system Design must include testing and commissioning requirements developed in consultation with the testing and commissioning agent, the Engineer, and the Operator.

Testing and commissioning must be carried out in accordance with the overall commissioning plan and program. Refer to Chapter 1, General.

12.2.6 Access for Servicing and Maintenance

Access for servicing and maintenance activities are critical to the effective operation of the LRT System.

The Design must allow sufficient space to access equipment for servicing and maintenance and must provide sufficient space between equipment to allow for removal and replacement of equipment.

Where practicable, overhead equipment should be located at a height which is accessible from the ground or can be accessed easily with a ladder. The Design should include a service platform if overhead equipment cannot be accessed with a ladder. A clear path of travel to remove equipment to the outside must be provided.

The Design must indicate available space and access paths with clear dimensions for maintenance, servicing, and replacement of equipment.

12.2.7 Warranty, Equipment Replacement, and Spare Parts

The Design should consider the use of materials and equipment which are locally supplied or have spare parts locally available. The Design should require a minimum warranty of two years on all parts and labour for all mechanical equipment. This will allow two heating and cooling seasons to verify equipment and system performance during the warranty period.

12.2.8 Electrical Motors and Electrical Support for Mechanical Systems

Refer to Chapter 11, Electrical, for voltage and phase requirements for motors equal to or less than ½ hp (0.37 kW). All motors equal to or less than ½ hp (0.37 kW) must be Electronically Commutated (EC) motors with provision for speed adjustment.

Refer to Chapter 11, Electrical, for voltage and phase of motors larger than ½ hp (0.37 kW). All motors greater than ½ hp (0.37 kW) must be premium efficient, “Inverter Duty” type.

Motors driven by Variable Frequency Drive (VFD) equipment must use dielectric grease on bearings and must incorporate a motor shaft grounding system using stainless steel brushes.

The mechanical system Design must include all control wiring, either line voltage or low voltage, and must be coordinated with the electrical system Design.

12.2.9 Variable Frequency Drive and variable Speed Adjustment for Mechanical Systems

For systems which do not operate at maximum capacity when they are enabled, means of varying the system capacity to suit the demand must be incorporated.

The mechanical system Design must include information on the supply and installation of VFD for building mechanical systems which operate at variable speeds or volumes. Speed adjustment for mechanical equipment should be done primarily with EC motors and speed control devices. Speed adjustment of systems using large motors must use multi-staged equipment with smaller size EC motors rather than a single large VFD if practicable. Adjustment of speed for mechanical equipment with VFD is only permitted if EC motors are not practicable.

If a VFD is used, it must be an integrated system (components and wiring) in a common enclosure having the following capabilities:

- BACnet communication with the BMS
- Hand-Off-Auto operation
- Isolated bypass
- Inlet and outlet inline filters

Refer to the Facility Consultant Manual for further requirements.

12.2.10 Heat Tracing

Heat tracing design must be coordinated between the mechanical and electrical Designers.

Insulation and heat tracing are required on all piping at risk of freezing. Temperature and moisture sensors for control of the heat tracing system must be provided. Heat tracing must be controlled by the BMS rather than a self-regulating control panel.

Accessibility for servicing and replacement of heat tracing must be considered in the Design.

12.2.11 Housekeeping Pads

As an Operator requirement, all major equipment must be mounted on a concrete housekeeping pad. Concrete housekeeping pads must be 100 mm to 150 mm thick and have a clearance of 100 mm to 150 mm around the equipment mounted on the pad. The curb of the housekeeping pad must be painted with high visibility yellow paint.

12.3 MECHANICAL SITE UTILITIES

The following section provides requirements for mechanical site utilities.

12.3.1 Natural Gas

Allowance for future expansion should be considered in sizing the gas supply to a facility. The Designer should confirm required spare capacity with the Engineer.

A single gas meter must be provided for each site. Protection for the gas meter is required if there is a risk of physical damage or vandalism. Bollards should be used to protect gas meters near Streets.

Gas meters must be capable of output for remote monitoring and reading. Gas meter output must be monitored through input into the BMS. Refer to Mechanical Handbook for further detail on gas meter input control point into the BMS.

12.3.2 Storm Sewers

Storm services for Stations and Ancillary Facilities must be by gravity flow where practicable.

Stormwater lift stations may be considered where gravity service is not practicable but must be reviewed and accepted by the Engineer. Refer to Chapter 16, Utilities and Drainage for stormwater management requirements.

Storm services must exit the building footprint below frost depth. Geotechnical information should be used to determine a safe depth for buried utilities. Heat tracing may be considered only if pipe installation below frost depth is not practicable.

12.3.3 Sanitary Sewers

Sanitary services for Stations and Ancillary Facilities must be by gravity flow where practicable.

Sanitary lift stations may be used when gravity service is not practicable. Refer to Chapter 16, Utilities and Drainage for sanitary lift station requirements.

Sanitary services must exit the building footprint below frost depth. Geotechnical information should be used to determine a safe depth for buried utilities. Heat tracing may be considered only if pipe installation below frost depth is not practicable.

12.3.4 Water Service

Allowance for future expansion should be considered in sizing the water service to a facility. The Designer should confirm the required flow with the Engineer.

Water services must include an isolation valve, reduced pressure backflow preventer, and meter.

The water entry into the facility and the meter must be located in a heated enclosure or in a heated mechanical room.

Should a facility require water service for fire protection, a combined water service for potable water and non-potable water should be used with the appropriate system separation.

Water service to a facility must be below frost depth. Geotechnical information should be used to determine a safe depth for buried utilities. Heat tracing may be considered only if pipe installation below frost depth is not practicable.

12.4 PLUMBING AND PIPING SYSTEMS

12.4.1 General Requirements

The following provides requirements for the various spaces in an Ancillary Facility. Each space has individual performance criteria.

Wet piping systems, including fire protection systems, are not permitted in the following spaces, even if drip trays or double walled piping are proposed:

- Traction Power Substation (TPSS) room
- Signals room
- Communications room
- Data centre

Cleanouts for storm or sanitary systems are not permitted in these spaces, and sanitary and stormwater pipes should not be located underneath. A floor drain with backflow prevention must be provided for any moisture ingress into the space. The floor drain discharge must be routed directly outside the space into an area which is not sensitive to moisture. The backflow prevention device must be located outside the space inside a valve box with full access. An individual backflow prevention device dedicated to the floor drain in each space must be provided and must be independent of the overall building backflow preventor.

Sanitary venting must not be routed through the noted moisture sensitive spaces.

Piping configuration and routing must be designed using flanges or unions so that piping does not have to be removed if equipment is replaced.

A capped drain valve with low point connection 1500 mm Above Finished Floor (AFF) must be provided for drainage in an emergency. All building plumbing systems and piping at risk of freezing must be in a heated environment inside the facility.

All plumbing systems and piping outside the heated facility at risk of freezing must be protected or located below frost depth. Geotechnical information should be used to determine a safe depth for buried utilities. Heat tracing may be considered only if pipe installation below frost depth is not practicable.

12.4.2 Piping and BMS Conduit Identification

Exposed piping must be painted/designated in accordance with the following Tables 12.1 and 12.2. The Designer must forward the painting requirements to the Engineer for review and approval.

Colour numbers for identification labels on piping systems, valves and equipment are defined in Federal Standard 595C [213].

Table 12.1 Piping and BMS Conduit Colours

Primary Colours for Piping	
Black	17038
Yellow	13591
Green	14193
Orange	12473
Brown	10115
Red	11350
White	17860
Aluminum	16515
Blue	15180
Grey	16293
Light Blue	15450
Purple	17155

Table 12.2 Application of Colour Codes to Type of Piping and BMS Conduits

Service	Background	Lettering	WHMIS Symbol	Legend
Sprinkler	Red	White	N/A	WET SPRINKLER
Wet Standpipe	Red	White	N/A	WET STANDPIPE
Dry Standpipe	Red	White	N/A	DRY STANDPIPE
Clean Agent (Fire)	Red	White	Yes	CLEAN AGENT
Natural Gas	Yellow	Black	Yes	[ ]kPa NATURAL GAS
Vacuum	Aluminum	Green	Yes	VAC.
Compressed Air	White	Green	Yes	[ ]kPa COMPRESSED AIR
Domestic Cold Water	Light Blue	White	N/A	DOMESTIC COLD WATER
Domestic Hot Water	Light Blue	White	N/A	DOMESTIC HOT WATER
Domestic Hot Water Recirculation	Light Blue	White	N/A	DOMESTIC HOT WATER RECIRC.
Heating Hot Water Supply	Yellow	Black	N/A	[ ]°C HOT WATER HEATING SUPPLY
Heating Hot Water Return	Yellow	Black	N/A	[ ]°C HOT WATER HEATING RETURN
Heating Glycol Supply	Yellow	Black	Yes	[ ]°C HEATING GLYCOL SUPPLY
Heating Glycol Return	Yellow	Black	Yes	[ ]°C HEATING GLYCOL RETURN
Chilled Glycol Supply	Green	White	N/A	CHILLED GLYCOL SUPPLY
Chilled Glycol Return	Green	White	N/A	CHILLED GLYCOL RETURN
Chilled Water Supply	Green	White	N/A	CHILLED WATER SUPPLY
Chilled Water Return	Green	White	N/A	CHILLED WATER RETURN
Condenser Water Supply	Green	White	N/A	CONDENSER WATER SUPPLY
Condenser Water Return	Green	White	N/A	CONDENSER WATER RETURN
Low Pressure Steam	Yellow	Black	Yes	[] kPa LP STEAM
Fuel Oil	Brown	Black	Yes	FUEL OIL
Refrigerant-Liquid	Grey	White	Yes	REFRIGERANT-LIQUID
Refrigerant-Gas	Grey	White	Yes	REFRIGERANT- GAS
Lubricating Oil	Brown	White	Yes	LUBE OIL
Engine Exhaust	Aluminum	Black	Yes	ENGINE EXHAUST
Boiler Feed Water	Yellow	Black	N/A	HOT BOILER FEED WATER

Softened Water	Blue	White	N/A	SOFT WATER
Chemical Feed Line	Green	Black	Yes	CHEMICAL FEED [CHEMICAL SYMBOL (S03) (P04)]
Drains	Aluminum	Green	N/A	DRAIN
Propane	Orange	Black	Yes	[ ] kPa PROPANE
BMS Conduits and wiring accessories	Orange	Black	N/A	BMS

12.4.3 Natural Gas Systems

The Design must provide low pressure gas in facilities based on area classification.

12.4.4 Storm Systems

Design parameters for a roof drainage system must be based on the 1:100 year storm event which is greater than the 15 mm in the Alberta Building Code (ABC) [152]. Refer to Chapter 16, Utilities and Drainage for information on the design storm parameters.

The Design must provide roof drainage systems consisting of roof drains and rainwater leaders within the facility which discharge to an underground storm lateral or main where practicable. Exterior gutters and downspouts should not be used, whether they discharge to grade or are connected to an underground storm pipe.

Discharge from rainwater leaders within a building to the building stormwater system must be by gravity flow where practicable. If a gravity flow system is not practicable, use of a duplex pump system with lift rail, four level float detection complete with local control panel with BMS monitoring and control may be acceptable. Refer to Section 12.8 for BMS points list associated with sump pumps.

The Design must include provision for storm sump pit cleaning. Sump pit diameter must not be less than 950 mm.

Refer to Chapter 10, Stations and Ancillary Facilities, for additional requirements.

12.4.5 Sanitary Systems

Sanitary discharge from plumbing fixtures within a building to the building sanitary system must be by gravity flow where practicable. If a gravity feed system is not practicable, use of a duplex grinder pump system with lift rail, four level float detection complete with a local control panel with BMS monitoring and control may be acceptable. Refer to Section 12.8 for BMS points list associated with sump pumps.

The Design must include provision for sanitary sump pit cleaning. Sump pit diameter must not be less than 950 mm.

Floor drains must include a continuous-drip trap primer.

Refer to Chapter 10, Stations and Ancillary Facilities, for additional requirements.

12.4.6 Domestic Hot and Cold Water Distribution System

The Domestic hot and cold water distribution system Design must provide isolation valves at each major branch to allow shutdown of specific zones or systems. Domestic hot and cold water piping must be completely insulated with recovery jacketing. Refer to Section 12.4.8.

Domestic hot water system sizing must be based on American Society of Plumbing Engineers (ASPE) Guidelines and Standards.

The Design must provide a hot water recirculation system following ASPE Guidelines and Standards. The Operator's requirement is to provide a hot water recirculation system if hot water cannot be delivered to the furthest area needing hot water within 15 seconds.

For seasonal water supply systems, provision for drain down and blowing out of lines for winterization must be included in the Design.

The Design must provide a capped drain valve with a low point connection for emergency drainage.

Refer to Chapter 10, Stations and Ancillary Facilities, for additional requirements.

12.4.7 Plumbing Fixtures

All plumbing fixtures must be vandalism resistant. Where practicable, components must be concealed or protected in enclosures.

Toilets must be Barrier-Free, elongated, white vitreous china, floor mounted, 6.1 litre/flush, with a heavy duty open front solid plastic toilet seat without a cover. The flush valve must be infrared sensor operated complete with manual override. The Engineer will advise the Designer if the flush valve is to be hardwired or battery operated.

Urinals must be wall mounted, vitreous china, 3.8 litre/flush, with an infrared sensor operated flush valve with manual override and carrier. The Engineer will advise the Designer if the flush valve is to be hardwired or battery operated.

12.4.7.1 Public Washrooms

Lavatories must be Barrier-Free, wall mounted, vitreous china, with overflow drain and wall carrier, infrared sensor operated faucet with 1.9 litre/minute spray head outlet and thermostatic mixing valve. The Engineer will advise the Designer if the faucet is to be hardwired or battery operated. If battery operated, a self-power-generation type faucet (water wheel) must be used.

12.4.7.2 Operator/Staff Washrooms

Lavatories for operator or staff washrooms must be Barrier-Free, oval, vitreous china, self-rimming/drop-in with overflow drain, and an infrared sensor operated faucet with 1.9 litre/minute spray head outlet and thermostatic valve. The Engineer will advise the Designer if the faucet is to be hardwired or battery operated. If battery operated, a self-power-generation type faucet (water wheel) must be used.

12.4.8 Plumbing Equipment and Material

12.4.8.1 Piping Identification

Pipe identification details are provided in Tables 12.1 and 12.2 above.

12.4.8.2 Piping and Pipe Fittings

Preferred or required piping material and fittings are provided in Table 12.3 below.

Table 12.3 Piping Material Schedule

System	Pipe	Fitting	Joint
Hydronic heating and cooling up to 120°C and 1035 kPa	Black steel Schedule 40, 50 mm or less	Threaded	Screwed
		Welding	Welded
		Mechanical Grooved	Clamped
	Black steel, Schedule 40, greater than 50 mm	Welding	Welded
		Mechanical grooved	Clamped
	Copper water tube type L, Drawn temper	Wrought copper	Soldered, 95-5 tin-antimony
		Cast copper	Soldered, 95-5 tin-antimony
Equipment drains and overflows	Galvanized steel, Schedule 40, ASTM A53-96 only	Galvanized threaded	Screwed
	Copper water tube, Type L, drawn temper	Wrought copper tin-antimony	Soldered, 95-5
Refrigerant	ACR copper	Wrought copper	Brazed
		Cast copper	Brazed
Domestic water above-grade	Copper water tube type L, drawn temper	Wrought copper	Soldered, 95-5 tin-antimony
		Cast copper	Soldered, 95-5 tin-antimony
DWV above-grade and buried	DWV copper (above-grade only)	Cast bronze	Soldered, 50-50 tin-lead
		Wrought copper	Soldered, 50-50 tin-leaded
	ABS	ABS	Solvent welded
	PVC	PVC	Solvent welded
Storm sewer, above-grade	DWV copper	Cast bronze	Solder, 50-50 tin-lead
		Wrought copper	Solder, 50-50 tin-lead
	ABS	ABS	Solvent welded
	PVC	PVC	Solvent Welded
Natural gas low pressure less than 1400 kPa, inside building	Black steel, Schedule 40 50 mm or less	Threaded	Screwed
		Welding	Welded
	Black steel, Schedule 40 greater than 50 mm	Welding	Welded

12.4.8.3 Insulation and Recovery Jacketing

Material and application details for insulation of equipment and piping are provided in Table 12.4.

Table 12.4 Pipe Insulation Thickness Schedule

Service Type	Insulation Type	Insulation Thickness (mm)
HOT WATER/GLYCOL HEATING		
50 and smaller	Hot pipe	25
65 and larger	Hot pipe	40
DOMESTIC HOT WATER AND RECIRCULATION		
40 and smaller	Hot pipe	12
50 and larger	Hot pipe	25
CHILLED WATER/GLYCOL		
	Hot pipe	12
All sizes	Cold pipe	25
DOMESTIC COLD WATER		
All sizes	Cold pipe	12
PLUMBING VENTS		
All sizes	Cold pipe	25
STORM SEWER PIPING		
All sizes	Cold pipe	12
Final 2 m section	Cold pipe	25
HEAT EXCHANGERS	Hot equipment	50
HOT WATER STORAGE TANKS	Hot equipment	50
WATER SOFTENERS	Cold equipment	25
ROOF DRAINS	Cold equipment	25

12.4.8.4 Mechanical Equipment Identification

Mechanical equipment must be painted as described in Table 12.5.

Table 12.5 Mechanical Equipment Painting

Mechanical Equipment Painting	
Heat Exchangers (hot)	Yellow
Heat Exchangers (cold)	Green
Hot Water Storage Tanks	Yellow
Cold Water Storage Tanks	Blue

12.4.8.5 Valves

All isolation valves must be located in accessible locations, away from high voltage lines or equipment. Isolation valves and unions must be provided, as required, to isolate equipment so entire systems do not have to be drained to remove failed components.

The Design must provide isolation valves on each major branch of a system to ensure zone isolation.

Table 12.6 identifies the application of each type of valve.

Table 12.6 Valve Schedule

Valve Type	Service
Globe and Angle Valves	Throttling, drain, and vents
Ball valves (<=100 mm) Design should use ball valves instead of butterfly valves for isolation on all sizes of hydronic systems (Operator preference)	Isolation, drain, and vents
Butterfly valves	Isolation (> 100 mm)
Radiation valves	Throttling
Automatic Pressure Independent Balancing Valve	Circuit Balancing Valves
Plug valves	Gas

12.4.8.6 Domestic Hot Water Heaters

Domestic hot water heaters may be natural gas fired or electric depending on the location and type of service. The heaters may be instantaneous, semi-instantaneous, or heaters with storage tanks to suit the application.

Hot water must be supplied by standard commercial grade domestic hot water heaters. The heaters must be located inside the mechanical room.

A fire proof drip tray and self-contained shut down device for the water and power to the heater must be provided. The self-contained shut down device must be mounted in the drip tray. Leakage onto the drip tray must be monitored by BMS.

Hot water heaters must be easily accessible for replacement, and floor drains must be provided near the heater to accommodate drainage from pressure relief valves.

Electric domestic hot water heaters must meet the requirements of CSA C22-110 and CSA C191 [214].

12.4.8.7 Pumps

All pump systems must be 100% duty/100% backup with the exception of domestic hot water recirculation pumps. All circulation pumps must be provided with pressure taps and gauges.

All circulation pumps with motors larger than 20 hp (14.91 kW) must be base mounted units, while circulation pumps with motors 20 hp (14.91 kW) or smaller must be vertically inclined, close coupled units.

All sump pumps must have rail lifting systems removal of the pumps for maintenance. Sump pumps for sanitary drainage must be grinder pumps. All sump pump control panels must be monitored and controlled by the BMS.

Piping, conduits, drains or any other obstructions must not be mounted above the pumps, to promote ease of removal. Clear access to pumps for maintenance must be provided.

12.4.8.8 Emergency Eyewash Station

An emergency eyewash station must be provided inside TPSS rooms, Signal rooms, communications rooms, and where batteries are stored. The emergency eyewash station must be a wall hung, gravity-fed, portable station with a built-in drain meeting ANSI Z358.1 [215].

12.5 VACUUM SYSTEM

A central vacuum system, either a permanent vacuum unit with associated piping, or piping with provision to connect to a portable vacuum unit, must be provided at all Stations. The system must include wet/dry vacuum piping. A complete system (vacuum unit and piping) must be provided for Multi-Modal Stations, and wet/dry vacuum piping for connection to a portable unit should be provided for Local Stations.

Refer to Chapter 10, Stations and Ancillary Facilities for definition of Multi-Modal and Local Stations.

12.5.1 Central Vacuum

The central vacuum must include a HEPA filter system with a filter gauge that indicates when the filter requires changing.

Electronic Monitoring Bleed Control (EMBC) must be included to signal an overload condition to the valve to allow more air in or turn off the system to protect the motor.

The circuit transformer must be housed in a metal junction box separate from the vacuum starter and both the transformer and the starter must be mounted near the EMBC. All components, panels, and breakers must be labeled.

Refer to BMS section for monitoring and remote on/off information.

12.5.2 Wet/Dry Vacuum Piping

Vacuum system piping should be specialty rated for the application. Rigid galvanized steel piping (2-1/8" OD 11ga.) should be used. Outlets must be provided at 20 m spacing under a Platform overhang. For centre-loaded Platforms, outlets must be provided on both sides of the Platform. For side-loaded facing Platforms only one set of outlets may be required subject to approval by the Engineer.

The Designer should consider providing a vacuum outlet in the mechanical or utility room where Heating Ventilation Air Conditioning (HVAC) equipment may require cleaning. The location of the vacuum outlets must be coordinated with the Engineer. Clean out plugs must be provided at the ends of horizontal mains and branches.

Main vacuum lines (headers) that provide connection to Station outlets must run parallel to the track under the cantilevered part of a Platform (refer to Figure 12.1). Headers must be installed on the outside of the Station bearing wall fixed to the underside of the Platform and must have only one point of entry into the Station building on each side. Vacuum lines should not be installed within confined space areas or crawl spaces.

All vacuum lines must be designed to minimize abrasive wear of the pipes and fittings; 90° short elbows or tees/wyes with short radii must not be used. When designing 90° direction changes, long radius elbows and tees/wyes with a 45° offset in the direction of flow must be used with the maximum tee radius practicable. This requirement applies to locations along the headers that connect to outlets and locations that enter the Station.

Cleanouts must be included at both ends of vacuum line headers.

12.6 HEATING, VENTILATION, AND AIR CONDITIONING SYSTEMS

12.6.1 Design Parameters

The following sections provide the indoor and outdoor design parameters for heating and cooling load calculations. Additional internal loads from equipment must be determined based on the heat rejection specific to each piece of equipment in individual spaces. Equipment heat rejection and temperature range tolerance must be determined for the specific equipment being used; the use of typical published data is not permitted.

Ventilation load calculations must be based on the ventilation requirements for individual spaces. Refer to specific requirements of individual spaces in this chapter.

Outdoor climatic design parameters for Edmonton are provided in the ABC [152] and in Chapter 1, General. The Engineer's requirement for outdoor winter design temperature is -40°C and summer design temperatures are 35°C dry bulb and 19°C wet bulb.

Indoor design temperature and relative humidity requirements are provided in Table 12.7.

Table 12.7 Design Indoor Temperature and Relative Humidity

Room or Area	Indoor Design Temperature Range	Indoor Design Temperature (Space Set Point)	Indoor Relative Humidity at mid-range of Design Temperature
TRACTION POWER	18°C to 25°C	20°C during heating season and 23°C during cooling season	N/A
COMMUNICATION SIGNAL, TELEPHONE, RADIO EQUIPMENT	18°C to 24°C	20°C during heating season and 22°C during cooling season	40% to 50% (to be confirmed by the Engineer)
DATA CENTRE	18°C to 23°C	20°C during heating season and 21°C during cooling season	40% to 50%
ELECTRICAL ROOM	18°C to 28°C	18°C during heating season and 25°C during cooling season	N/A
WASHROOMS	20°C to 27°C	22°C during heating season and 25°C during cooling season	N/A
UTILITY/JANITORIAL STORAGE/VACUUM ROOM	18°C to 27°C	20°C during heating season and 24°C during cooling season	N/A
OFFICE AREA/STAFF ROOM/SECURITY ROOM	18°C to 25°C	21°C during heating season and 23°C during cooling season	20% to 30% during winter
ELEVATOR MACHINE ROOM/HOISTWAY	Refer to the requirements of the elevator machinery and equipment and AEDARSA Regulations	Refer to the requirements of the elevator machinery and equipment and AEDARSA Regulations	Refer to the requirements of the elevator machinery and equipment and AEDARSA Regulations
Kiosk/Retail	Consult LRT for specific vendor requirements.	Consult LRT for specific vendor requirements.	Consult LRT for specific vendor requirements.

12.6.2 Heating, Cooling, and Ventilation

12.6.2.1 Traction Power Substations

Traction Power Substation (TPSS) rooms must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards, and any other criteria identified by the Engineer.

TPSS rooms are not intended for occupancy.

Exhaust for any battery stations inside the TPSS room must be provided. Filtered outdoor air or transfer air from the rest of the facility may be used as makeup for the exhaust.

The Design must provide primary heating and backup heating. Backup heating must be 100% redundant.

The Design must provide mechanical cooling to the TPSS room with the option of turning off the compressors when outdoor air temperature is acceptable for heat dissipation. Outdoor air must not be used for cooling.

Provide N + 1 level of redundancy for the cooling system. Equipment must be lead-lag with at least one unit capable of satisfying 75% of the maximum cooling load.

HVAC equipment should be placed outside the TPSS room where practicable to allow servicing, maintenance, and replacement of equipment without entering the space.

12.6.2.2 Communications and Signal Rooms

Communications rooms and Signals rooms must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards, and any other criteria identified by the Engineer.

Communications and Signal rooms are not intended for occupancy.

Exhaust for any battery stations inside the room must be provided. Filtered outdoor air or transfer air from the rest of the facility may be used as makeup for the exhaust.

The Design must provide primary heating and backup heating. Backup heating must be 100% redundant.

The Design must provide mechanical cooling to the room with the option of turning off the compressors when outdoor air temperature is acceptable for heat dissipation. Outdoor air must not be used for cooling. Provide N + 1 level of redundancy for the cooling system. Equipment must be lead-lag with at least one unit capable of satisfying 75% of the maximum cooling load.

For equipment in a hot isle / cold isle configuration, the Design must provide direct ductwork connections for the discharge of hot air from the equipment. Mixing of the warm return air and cold supply is not permitted.

The Design must provide humidification to the room unless the Engineer confirms that it is not required.

HVAC equipment should be placed outside the room where practicable to allow servicing, maintenance, and replacement of equipment without entering the space.

12.6.2.3 Data Centres

Data Centres must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards, and any other criteria identified by the Engineer.

Data Centres are not intended for occupancy.

Exhaust for any battery stations inside the room must be provided. Filtered outdoor air or transfer air from the rest of the facility may be used as makeup for the exhaust.

The Design must provide primary heating and backup heating. Backup heating must be 100% redundant. The Design must provide mechanical cooling to the room with the option of turning off the compressors when outdoor air temperature is acceptable for heat dissipation. Outdoor air must not be used for cooling. Provide N + 1 level of redundancy for the cooling system. Equipment must be lead-lag with at least one unit capable of satisfying 75% of the maximum cooling load.

Equipment and system sizing must prevent short cycling, to avoid impacting the lifespan of equipment.

For equipment in a hot isle / cold isle configuration, the Design must provide direct ductwork connections for the discharge of hot air from the equipment. Mixing of the warm return air and cold supply is not permitted.

The Design must provide humidification to the room unless the Engineer confirms that it is not required.

HVAC equipment should be placed outside the room where practicable to allow servicing, maintenance, and replacement of equipment without entering the space.

12.6.2.4 Electrical Rooms

Electrical rooms must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards provided in this chapter, and any other criteria identified by the Engineer.

Electrical rooms are not intended for occupancy.

Exhaust for any battery stations inside the room must be provided. Filtered outdoor air or transfer air from the rest of the facility may be used as makeup for the exhaust.

The Design must provide primary heating and backup heating. Backup heating must be 100% redundant.

The Design may use outdoor air for cooling the space is acceptable provided it is filtered. If mechanical cooling is required, N + 1 level of redundancy for the cooling system must be provided. Cooling equipment must be lead-lag with at least one unit be capable of satisfying 75% of the maximum cooling load.

12.6.2.5 Washrooms and Janitor Rooms

Washrooms and janitor rooms must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards provided in this chapter, and any other criteria identified by the Engineer.

The Design must include exhaust and ventilation as per American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) 62.1 [216].

Heating and cooling systems must satisfy the indoor temperature and humidity requirements based on design conditions.

HVAC equipment should be placed out of reach where practicable to reduce the risk of vandalism.

12.6.2.6 Utility Rooms, Mechanical Rooms, Service Rooms, and Vacuum Rooms

These spaces must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards provided in this chapter, and any other criteria identified by the Engineer.

The Design must include exhaust and ventilation as per ASHRAE 62.1 [216].

Heating and cooling systems must satisfy the indoor temperature and humidity requirements based on design conditions.

12.6.2.7 Elevator Machine Room and Hoistway

Elevator machine rooms and elevator hoistways must have an HVAC system which meets or exceeds the requirements of the elevator machinery and equipment manufacturer and of the Alberta Elevating Devices and Amusement Rides Safety Association (AEDARSA).

12.6.2.8 Office Areas, Staff Rooms, and Security Rooms

These spaces must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards provided in this chapter, and any other criteria identified by the Engineer.

The Design must include exhaust and ventilation as per ASHRAE 62.1 [216].

Heating and cooling systems must satisfy the indoor temperature and humidity requirements based on design conditions.

Open office areas and individual offices must be on separate thermostatic zone control. The Designer must confirm thermostatic zone control requirements with the Engineer.

12.6.2.9 Platforms

Heating, cooling, and ventilation are not required for Platforms.

12.6.2.10 Shelters

Patron shelters must have ceiling mounted radiant heating in semi-enclosed waiting areas. Only indirect gas fired heating units are acceptable if gas heating is chosen. Heating units must be controlled by BMS and timer/occupancy sensors. Monitoring of the flue temperature from the heating units must be provided. Refer to the BMS controls points in the Mechanical Handbook.

Heating unit flue termination and discharge on the underside of a Platform canopy is not permitted.

The Design must include ventilation to reduce heat buildup inside the shelter during the summer.

12.6.2.11 Crawlspaces

Crawlspaces must include an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards provided in this chapter, and any other criteria identified by the Engineer.

Ventilation providing a minimum of 1 Air Change per Hour (ACH) for a crawlspace must be included in the Design. Heating of crawlspaces may be required based on the utilities and equipment in the crawlspace.

If equipment is placed inside a crawlspace, the area must be sized to provide clear space for maintenance, servicing, and replacement of the equipment.

12.6.2.12 Generator Rooms

Generator rooms must have an HVAC system which meets or exceeds the requirements indicated below, applicable codes and standards provided in this chapter, and any other criteria identified by the Engineer.

Ventilation of generator rooms must incorporate exhaust air dampers, return air dampers, outdoor air intake dampers, and a minimum combustion air damper. A space temperature sensor must be used to modulate exhaust, return, and outdoor air dampers. The combustion air intake damper must operate as a two-position damper that is hardwire interlocked with the generator.

For generator rooms in residential areas the Designer must undertake a detailed assessment of the need for noise control. Muffler systems must be able to meet the noise level restrictions required under the City of Edmonton Community Standards Bylaw 14600.

Vibration isolators on muffler piping and spring isolators on the hangers for exhaust pipes must be provided to mitigate vibration and expansion / contraction.

Refer to Chapter 11, Electrical, for additional requirements.

12.6.2.13 Exterior Stairs and Ramps

For rehabilitation projects, exterior stairs and ramps at existing facilities that are already provided with snow and ice melt systems must be updated to meet current standards and requirements. The Designer must confirm specific requirements with the Operator and Engineer.

Existing infrastructure currently without snow and ice melt systems and all stairs and ramps for new facilities do not require snow and ice melt systems.

12.6.3 Heating, Ventilation, and Air Conditioning Equipment

The following provides general requirements for HVAC equipment. The Design must include HVAC equipment which meets or exceeds the requirements indicated below, applicable codes, standards, and criteria provided in this chapter, and any other criteria identified by the Engineer.

12.6.3.1 Heating

The Design must provide appropriate heating equipment to maintain space temperature set point as indicated in the space requirement. Equipment must suit the overall heating system for the space, and must meet requirements for energy efficiency, redundancy, ability for future expansion, durability, ease of operation, and availability of spare parts.

All heating equipment must be able to vary the output to meet the heating load for energy efficiency. All equipment must be minimum commercial grade. If required by the Engineer, industrial grade quality equipment should be used.

All heating equipment should be BACnet compatible. If equipment with BACnet connection is not available, use of a MODBUS connection or relay contact may be acceptable.

The Designer must review equipment control compatibility with BMS with the Engineer.

12.6.3.2 Cooling

The Design must provide appropriate cooling equipment to maintain space temperature set point as indicated in the space requirement. Equipment must suit the overall cooling system for the space, and must meet requirements for energy efficiency, redundancy, ability for future expansion, durability, ease of operation, and availability of spare parts.

All cooling equipment must be multi-staged or be able to vary the output to closely match the cooling load for energy efficiency. All equipment must be minimum commercial grade. If required by the Engineer, industrial grade quality equipment should be used.

All cooling equipment should be BACnet compatible. If equipment with BACnet connection is not available, use of a MODBUS connection or relay contact may be acceptable.

The Designer must review equipment control compatibility with BMS with the Engineer.

12.6.3.3 Ventilation

The Design must provide appropriate ventilation systems and equipment to maintain ventilation requirements as for each space. Equipment must suit the overall ventilation system for requirements of energy efficiency, redundancy, ability for future expansion, durability, ease of operation, and availability of spare parts.

Ventilation systems should use direct drive fans for energy efficiency and reduced maintenance. All direct drive fans must have speed adjustment for balancing. EC motors with adjustment must be used for fans. If the use of EC motors is not practicable, the Design should provide VFD for balancing and speed adjustment.

A lift rail inside air handling units must be provided if the fan motor is larger than 10 hp (7.46 kW).

All equipment must be minimum commercial grade. If required by the Engineer, industrial grade quality equipment should be used.

All ventilation equipment should be BACnet compatible. If equipment with BACnet connection is not available, use of a MODBUS connection or relay contact may be acceptable.

The Designer must review equipment control compatibility with BMS with the Engineer.

The Designer should consider zoning and occupational thermal comfort control when selecting ventilation systems and equipment. For larger facilities with multiple zones, variable air volume systems with variable supply air handing units as well as variable air volume terminal boxes complete with reheat coils may be used where applicable.

Large air handling units should be designed with a fan array system rather than a single larger fan and motor for ease of maintenance and for system redundancy.

12.6.4 Heating, Ventilation, and Air Conditioning Materials

12.6.4.1 Ductwork insulation

All intake, supply, and exhaust ductwork and equipment must be identified and insulated as described in Table 12.8, 12.9, and 12.10.

Table 12.8 Mechanical Ductwork Identification

Service	Background	Colour	Lettering
Return air	Blue	White	RETURN AIR
Supply air	Blue	White	SUPPLY AIR
Mixed air	Blue	White	MIXED AIR
Combustion air	Blue	White	COMBUSTION AIR
Relief air	Blue	White	RELIEF AIR
General exhaust air	Blue	White	GENERAL EXHAUST AIR
Toilet exhaust	Blue	White	TOILET EXHAUST AIR

Table 12.9 Duct Equipment Identification Labels

Service	Background	Lettering
Cleaning and service access	Yellow	Black
Controls, including heat sensors	Black	White
Dampers (backdraft, balance, and control)	Blue	White
Fire dampers	Red	White
Smoke dampers and detectors	Red	White

Table 12.10 Duct Insulation Schedule

Service Type	Insulation Type	Insulation Thickness (mm)
Exhaust and relief ducts within 3 m of exterior openings	Hot duct	25
Relief ducts and plenums	Hot duct	25
Supply ducts and plenums	Hot duct	25
Combustion air	Cold duct	50
Outside air	Cold duct	50
Mixing plenums	Cold duct	50
Supply air plenums	Cold duct	25
Supply ducts	Cold duct	25
Supply and return ducts exposed to outdoors	Cold duct	50
Supply and return ducts in cold attic spaces	Cold duct	50
Supply and return	Acoustic	25
Supply and return exposed to outdoors	Acoustic	50
Plenums	Acoustic	25
Boilers	Breeching	50
Domestic hot water heaters, atmospheric burners	Breeching	25
Furnaces	Breeching	25
Gas-fired unit heaters	Breeching	25
Indirect gas-fired air handling units, forced air burners	Breeching	25
Indirect gas-fired air handling units, atmospheric burners	Breeching	50

Supply ductwork must be acoustically lined with a minimum of 25 mm acoustical insulation. Exhaust ductwork on the return side of ventilating equipment must be acoustically insulated up to and including the first elbow before the unit. Casings of all ventilating equipment must be insulated.

Major equipment must be internally protected with perforated aluminum liners.

Exhaust ducts and outdoor air intake ducts within 3 m of exterior walls or openings must have 50 mm of thermal insulation.

Exterior ductwork must have 50 mm thermal insulation with aluminum cladding.

Acoustical insulation must be included to meet the requirements of the project noise study prepared by an acoustical consultant.

12.6.4.2 Dampers and Louvres

All dampers must to be provided with end switches that signal confirmation of opening and closing back to the BMS. All dampers to the outside must be ultra-low leakage, insulated type, and include extreme cold weather seals. All louvres must be drainable, allowing the largest effective area. All louvres must be 150 mm in depth and must be sized to have a velocity 20% below the rain penetration rated velocity.

12.6.4.3 Ductwork

All ductwork should be low pressure and low velocity galvanized metal ducting unless required otherwise for a specific application. The use of stainless steel and other special types of ducting material may be required for specific applications.

Medium or high pressure and velocity ductwork may only be used when required for a specific application. The use of medium or high velocity ductwork solely to suit architectural requirements is not acceptable.

12.7 SUSTAINABILITY

All buildings mechanical systems should follow the City of Edmonton Sustainable Building Policy C532. Where there are conflicts between space requirements and the policy, the Designer must request a variance from the Engineer. Refer to Chapter 1, General.

Facility mechanical systems must meet all applicable codes, standards, and the Engineer’s requirements.

The Designer must confirm the sustainability approach and outline the energy efficiency of systems with the Engineer.

12.8 BUILDING MANAGEMENT SYSTEM

The BMS includes equipment that is necessary for monitoring and controlling HVAC equipment at Platforms, Stations, Utility Complexes, and any other LRT facilities.

LRT security, notification, and fire alarm systems are on separate control systems. The BMS is only provided with an interconnection from some of the other systems for alarms.

Platforms, Stations, Utility Complexes, LRT Operations and Maintenance Facilities (OMF), tunnels, and pedways on the LRT System must be provided with building HVAC and plumbing systems which are controlled and/or monitored by the BMS. Dedicated controllers within each facility or building must be connected back to the LRT Operations Control Centre (OCC).

Since the ETS BMS is a separate system from the City of Edmonton (COE) corporate BMS, there will be additional requirements to those identified in the COE Facility Design & Construction Consultant Manual.

Refer to Section 12.4.2 for BMS conduit and material identification.

12.8.1 Existing Building Management System Infrastructure

The existing LRT BMS is supplied by Delta Controls and is administered by ETS Technical Services.

The Designer must contact ETS Technical Services for the most current versions of hardware, software, and network configuration, as well as the current BMS controls contractor.

12.8.1.1 Main Network

ETS Technical Services controls all network systems and architecture and will provide current BMS network topology and requirements to the Designer.

12.8.1.2 Facility Network

The BMS networks within each facility consist primarily of copper network cabling, except where conventional copper network cabling (Cat 6) distances are exceeded. Where copper network cabling distances would be exceeded, fibre optic network cabling must be used. Refer to Chapter 8, Communications for more details on communications networks.

All branch controllers must be connected to the nearest network element. ETS Technical Services must be consulted for all network connections.

Unmanaged switches are not permitted as part of the BMS Design. ETS Technical Services will provide managed switches when required by the Design.

Signal amplifying devices must not to be used to overcome cabling distance limitations of copper network cable. Individual fibre optic media converters should not be used unless approved by the Operator. All copper cable runs must also conform to BICSI/TIA standards for installation. These standards apply to any Cat 6 installation described in this chapter.

The Designer should note that there are two independent BMS within DLM and ROW buildings on the DLM site:

- Corporate BMS administered by Facility Management Services (FMS)
- ETS BMS administered by ETS Technical Services

12.8.1.3 LRT Operations Control Centre

BMS monitoring is conducted on a 24/7 basis from the LRT OCC.

The web page access to the main alarm system is accomplished via the Owner’s Entelliweb. Individual workstations can access the BMS for monitoring.

12.8.2 New Building Management System Infrastructure General Requirements

A new Direct Digital Control (DDC) BMS must be provided in each new facility or addition to existing facilities to monitor and control the building systems described below.

12.8.2.1 Building Management System Intent

Fully integrated controls must be provided to control and/or monitor facility systems and equipment as part of the overall BMS.

12.8.2.2 System Additions

New BMS equipment provided for a new facility must be added onto the existing BMS system by extending the existing BMS main network to the new facility and connecting the new facility network to the extended main network.

All new BMS equipment must conform with and be fully integrated into the existing BMS system.

The Designer must include BMS drawings showing wiring, I/O schematics, and communication protocols (e.g. riser diagrams) as part of the mechanical record drawing package.

12.8.2.3 Interfacing Requirements

The BMS must interface with other systems to provide monitoring. The interconnection requirements and monitoring functions must be clearly specified between the respective systems.

The BMS Systems Interface Matrix, included in Appendix 12-A, identifies the major LRT functions by element, that are controlled centrally. The matrix provides an overview of the required interrelationships including those with the BMS. The LRT Communications Handbook describes the specific BMS interrelationships for the various systems.

12.8.3 Building Management System Equipment and Hardware Requirements

12.8.3.1 Main Network

To extend the existing main network fibre optic cabling to a new facility, the Designer must treat the BMS panel as another ethernet device to connect to the extended ethernet network and cable it in the same manner as an IP-based camera, sign, or phone. ETS Technical Services must be consulted for all device connections to the main network.

12.8.3.2 Facility Network

The facility network is an extension of the main network from the main communications room and is the same network used for all IP devices at all the points in the Station. Each of these switches must have dedicated ports provisioned for the BMS panels. ETS Technical Services must be consulted for all device connections to the main network.

12.8.3.3 Main Control Panels

Fully distributed BMS control panels must be provided in communication, mechanical, electrical, Signal, and other rooms as required to control the relevant systems.

Controllers must be provided in all mechanical, electrical, and communication rooms.

All new controllers must be fully compatible with the existing control system. Upgrading of all software and firmware for existing BMS controllers may be required to interface the new controllers to existing controllers. Where practicable, upgrading should include all existing controllers with the overall objective of maintaining the newest software and firmware versions throughout the BMS system. ETS Technical Services will provide current practices and protocols for integrating controllers into the existing system.

New controllers must be fully capable of operating in stand-alone mode.

Primary power supplies for all main control panels must be provided via the facility Uninterruptable Power Supply (UPS) system. The power supply should be supervised, provide individually fused outputs, be self-contained within the respective controller or stand-alone within an enclosure, and have proper identification.

Free standing power transformers, mounted on small 100 mm x 100 mm boxes placed throughout a facility, are not acceptable.

12.8.3.4 Local Control Panels

Local Control Panels (LCP) may be used in remote applications or where multiplexing of small numbers of input/output points is required. LCP must be fully programmable controllers. ETS Technical Services must be consulted for networking requirements when LCP are used.

All LCP must be enclosed within metal enclosures complete with lockable door latches.

The primary power supply for LCP must be provided from the facility power system. Central emergency power must be used, if provided in the facility, as the primary power supply for all LCP. Individual or central UPS must be provided for the secondary power system to the LCP.

12.8.3.5 Expansion Capabilities

Stand-alone controllers must accommodate 25% spare input and 25% spare output point capability for future input/output additions. Spare point capacity, through the future addition of input/output expansion boards, may be acceptable.

12.8.3.6 Local, Facility, and Remote Operator Workstations

Access to the BMS is through a web page system (Entelliweb). The Designer must confirm the requirement for any dedicated Operator Workstations (OWS) for the facility with the Operator.

12.8.3.7 Sensors and Devices

Upon request, ETS Technical Services will provide a list of acceptable sensors and device type products for the Design.

12.8.4 Control Logic Software, Graphics, and Alarming Requirements

12.8.4.1 Control Logic Software

The Designer must make provision for control logic sequences that incorporate all BMS monitoring and control functions for new facilities and include any required modifications to existing control logic sequences.

12.8.4.2 Building Management System Graphics

Graphics must be provided for all BMS monitored and controlled systems, and must be based on graphic formats previously used for existing facilities for consistency.

In some instances, modifications and/or additions may be required to some graphics to accommodate new facilities.

Building Management System Alarming

All BMS alarming musty be segregated and logged as follows.

Security related alarms must be assigned to the ETS Security OCC with the exception of door access alarms. All maintenance alarms must be initially assigned to the ETS Security OCC. The LRT OCC will then dispatch to maintenance as required. All other alarms must be assigned to the LRT OCC. All alarms must also to be logged at the BMS servers.

Individual alarm conditions must be specified for the various system points to alert the Operator's personnel to alarm conditions normally expected from BMS systems being monitored and controlled. Where practicable, alarm conditions in existing facilities should be used in new facilities on similar systems.

12.8.5 Requirements for the Building Management System Monitoring and Control of Systems

This section provides the monitoring and control function requirements for the various types of systems and/or equipment that may be provided in a facility or tunnel. The requirements should be applied based on the types of systems that have been selected for each facility

An appropriate number of control points should be provided to confirm fully operational HVAC systems and equipment meeting the intended sequence of operation.

An appropriate number of monitoring points should be provided to allow full diagnostics of HVAC systems and equipment for performance and alarms. Ability for remote troubleshooting of Operation and Maintenance (O&M) must be incorporated into the control and monitor points list.

Refer to the ETS Technical Services BCP for control and monitoring points, and connection methodology for various systems and equipment.

The equipment/systems for BMS control and monitoring include:

- Air handling systems monitoring and control
- Damper control
- Compressed Air Systems Monitoring (AIR)
- Boiler Monitoring and Control (BLR)
- Cooling Systems Monitoring and Control (CLG)
- Carbon Monoxide Condition Monitoring (CMO)
- Detection of leakage from domestic hot water tank heater on drip tray
- Electrical Systems Monitoring (ELC)
- Elevator Monitoring (ELV)
- Escalator Monitoring and Control (ESC)
- Fire Suppression Systems Monitoring (FIR)
- Natural Gas Control (GAS)
- Emergency Generator Ventilation Control and Monitoring (GEN)
- General Exhaust System Monitoring and Control (GEX)
- Glycol Heating Systems Monitoring and Control (GLY)
- Heating Systems Monitoring and Control (HTG)
- Heating Water Systems Monitoring and Control (HWx)
- Lighting Monitoring and Control (LTG)
- Outdoor Air Condition Monitoring (OAT)
- HVAC equipment push button
- Smoke control monitoring
- Sump Monitoring (SMP)
- Vault Monitoring (VLT) - high water level alarm

- Space Temperature Monitoring (SPT)
- Alarm conditions are to be set at both high and low limits consistent with similar space alarm conditions in existing facilities
- Uninterruptible Power Supply (UPS) system monitoring
- Automatic Transfer Switch (ATS) monitoring
- Main power distribution monitoring
- Switchgear monitoring
- Marshalling Cabinet Monitoring (MC)
- Crew advisory lights system monitoring
- Run time counter for all HVAC equipment where applicable
- Central vacuum system
- Heat tracing control and monitoring
- Switch blower control

12.8.6 Training

Training must be provided to the Operator's staff for all new facilities and their related systems, including any expansion of the existing BMS system. BMS training is limited to BMS architecture for any new Station and the control sequence strategies for new equipment.

12.8.7 Building Management System Operating and Maintenance Manuals

Refer to Chapter 1, General, for requirements on O&M data and record plans.

BMS documentation must include loop drawings.

12.8.8 BMS and Equipment/System Interface Wiring Drawings

As part of the Design documents, the Designer must provide wiring diagrams and system schematics including BMS interface with equipment and systems monitored and controlled by the BMS.

Points schedule on drawings c/w wiring conduits. (Loop drawings).

Indicate which network (LRT or COE) for BMS.

Coordinate with electrical and communications.

12.9 FIRE PROTECTION SYSTEMS

The Design must provide a fire protection system to meet the requirements of ABC, Alberta Fire Code (AFC) [176], and the AHJ in new facilities including service areas, tunnels, and Utility Complexes. The Design of the fire protection system must be approved by the City of Edmonton's insurance providers.

Any modifications or extensions to fire protection and tunnel emergency ventilation systems must be documented and updated in the ETS Fire Protection Manual.

Fire protection equipment currently used on the LRT System includes:

- Dry pipe sprinkler systems
- Wet pipe sprinkler systems
- Tunnel fire hose cabinet racks
- Station fire hose cabinets
- Clean agent fire suppression systems

- Portable fire extinguishers
- Firefighter phones
- Fire hydrants

12.9.1 Fire Protection System Operation and Maintenance Manuals

Refer to Chapter 1, General, for requirements on O&M data and record plans.

12.9.2 Standpipe Fire Hose Systems

A standpipe system must be installed in locations where required by code. Standpipe systems must be designed to NFPA 14 [217] with hose connections meeting the standards set out in NFPA 1963 [218] and NFPA 130. The fire hose system must be split into two systems dependent on the size of the facility and the location within the facility. The system is independent of the sprinkler system (if applicable).

A dry standpipe system must be used in underground tunnels and for the hose cabinets on Multi-Modal Station Platform and mezzanine levels, where required.

Bonding jumpers must be specified on all mechanical grooved piping Victaulic connections on piping systems in tunnel areas.

12.9.2.1 Fire Hose Locations

Stations

Hose stations may be required on Grade Separated Platforms. If hose stations are included, the hose stream must be able to reach all areas of each LRV while the Train is stopped within the length of the Platform. Hose stations must be located in a hose cabinet containing hoses, fittings, and a portable fire extinguisher (if required). Hose stations must be installed behind break glass or locked glass panels to limit vandalism.

Connections for Fire Rescue Services (FRS) must be provided for all standpipe systems.

Tunnels

Hose stations, valves, and standpipe connections in tunnels must be located no more than 1.2 m above Top of Rail (TOR) and must be clear of the Design Vehicle Dynamic Envelope (DVDE). Each hose station must have a fluorescent orange cover.

Tunnels must be split into valved standpipe sections, so that a break in the main line can be valved off with the remaining hose stations being useable.

Each hose station must be equipped with two 15 m lengths of service attack hose. Each hose length must have a diameter of 44 mm complete with 38 mm couplings. The hose must be double jacketed.

Fire hose nozzles must be FRS standard fog and straight steam nozzle types.

12.9.2.2 Fire Rescue Services Connections

The Design must include FRS connections in accordance with ABC [152], AFC [176], and building code references to NFPA standards. The Designer must coordinate locations with FRS.

FRS connection locations must have a lamacoid nameplate indicating the area being served and the FRS connection number.

12.9.2.3 Temporary Standpipe

A temporary dry standpipe At-Grade must be provided if Station or tunnel construction impedes FRS access to existing hydrants or buildings.

The standpipe must have a FRS connection at each end and hose valve takeoffs as required by FRS. The system must be braced and anchored to prevent movement during use.

12.9.2.4 Valves

Check and isolation valves are required at each end of tunnel fire hose systems. Butterfly valves must be used.

Valve locations must be reviewed by and coordinated with FRS and the Engineer.

12.9.3 Sprinkler Systems

Sprinkler systems in areas subject to freezing must be dry pipe type. The sprinkler system must be independent of the hose system.

Drain valves for the sprinkler system must be located in easily accessible locations.

Sprinkler systems must not to be installed in TP equipment rooms, Signal rooms, communications rooms or data centres.

12.9.4 Clean Agent Fire Suppression Systems

Clean agent fire protection systems must be provided in:

- TP rooms
- Signal rooms
- Communication rooms
- Data centres

Clean agent fire protection systems must be Underwriter's Laboratories of Canada (ULC) listed and designed to meet the requirements of NFPA 2001 [219].

The clean agent system must meet the following requirements:

- Zero ozone depletion potential
- Global warming potential less than 1
- Non-toxic or low toxicity at design concentrations
- Not contain CFCs or HCFCs subject to refrigerant phase-out
- 20-year warranty against regulatory bans or fluid restrictions

12.9.5 Fire Extinguishers

Selection and placement of fire extinguishers must comply with ABC [152], AFC [176], and NFPA 10 [220].

The Designer must select fire extinguishers that are applicable, based on the type of fire expected:

- Class A – wood, paper, cloth
- Class B – flammable liquid or combustible liquid, fat, or grease
- Class C – energized electrical equipment

Classification of hazard may be found in NFPA 10, 1-5. Additional extinguishers may be required adjacent to welding operations, cooking operations, where combustibles are stored, near internal-combustion engines, and adjacent to flammable liquids storage and handling areas.

Extinguishers must be located based on their hazard and rating using AFC Table 6.2.3.3 and Table 6.2.3.5.

12.10 TUNNEL VENTILATION & SMOKE CONTROL

The Design must satisfy all requirements of NFPA 130 Standard for Fixed Guideway Transit & Passenger Rail Systems, and must be coordinated with the electrical Design and consider the Operator's requirements.

The two major types of ventilation systems that currently exist in the LRT System are the base Tunnel and underground Station ventilation system and the emergency tunnel and underground Station ventilation system.

The base tunnel and underground Station ventilation system provides an acceptable level of environmental quality for Patrons and service personnel. Heating at portals may be required where the stack effect is a concern and freezing conditions may result in damage to LRT structures and equipment. Each location must be evaluated individually.

The emergency tunnel and underground Station ventilation system provides fire and smoke control in emergency situations.

12.10.1 Base Tunnel Ventilation

The ventilation of the tunnel systems is achieved by three methods.

The piston effect of the Light Rail Vehicles (LRV) moving through the tunnels provides required ventilation under normal conditions. Blockage ratio, impedance, and the speed of the Train are used in the design of this ventilation. Tunnel and underground Station ventilation is also provided by the forced air fan smoke removal systems and the natural stack effect, which is dependent on the exterior air temperature and the temperature inside the tunnels.

12.10.2 Emergency Tunnel Ventilation

Emergency ventilation of underground Stations is primarily achieved by the forced air fan smoke removal system.

Dampers and fans that respond to emergency conditions must be designed to be automatically controlled through a ULC listed fire alarm panel with secondary monitoring from the LRT OCC. Manual override control must be provided at the Station. The manual override control system must be verified by the Operator.

Under the condition of no piston effect, the forced air system must be able to purge the emergency area at a rate approved by FRS. Additions to an existing ventilation system must be compatible with and fully integrated to the existing system.

Fans designated for the control and direction of air flow must be:

- Reversible under emergency conditions, with full reversing within 30 seconds
- Sized to provide air velocity of a minimum 60 m/minute in all tunnels leading from a Station

- Complete with internal brakes to bring fans to zero speed before starting and/or change of air flow direction

Design and specification of smoke ventilation and management system should be ULC compliant in accordance with ABC and AFC. NFPA Standards including but not limited to NFPA 130 must be used as guidelines unless otherwise referenced in ABC and AFC.

Primary monitoring of the emergency tunnel ventilation system is by a third-party monitoring agency and secondary monitoring is by the LRT OCC.

CHAPTER 13

Corrosion and Stray Current

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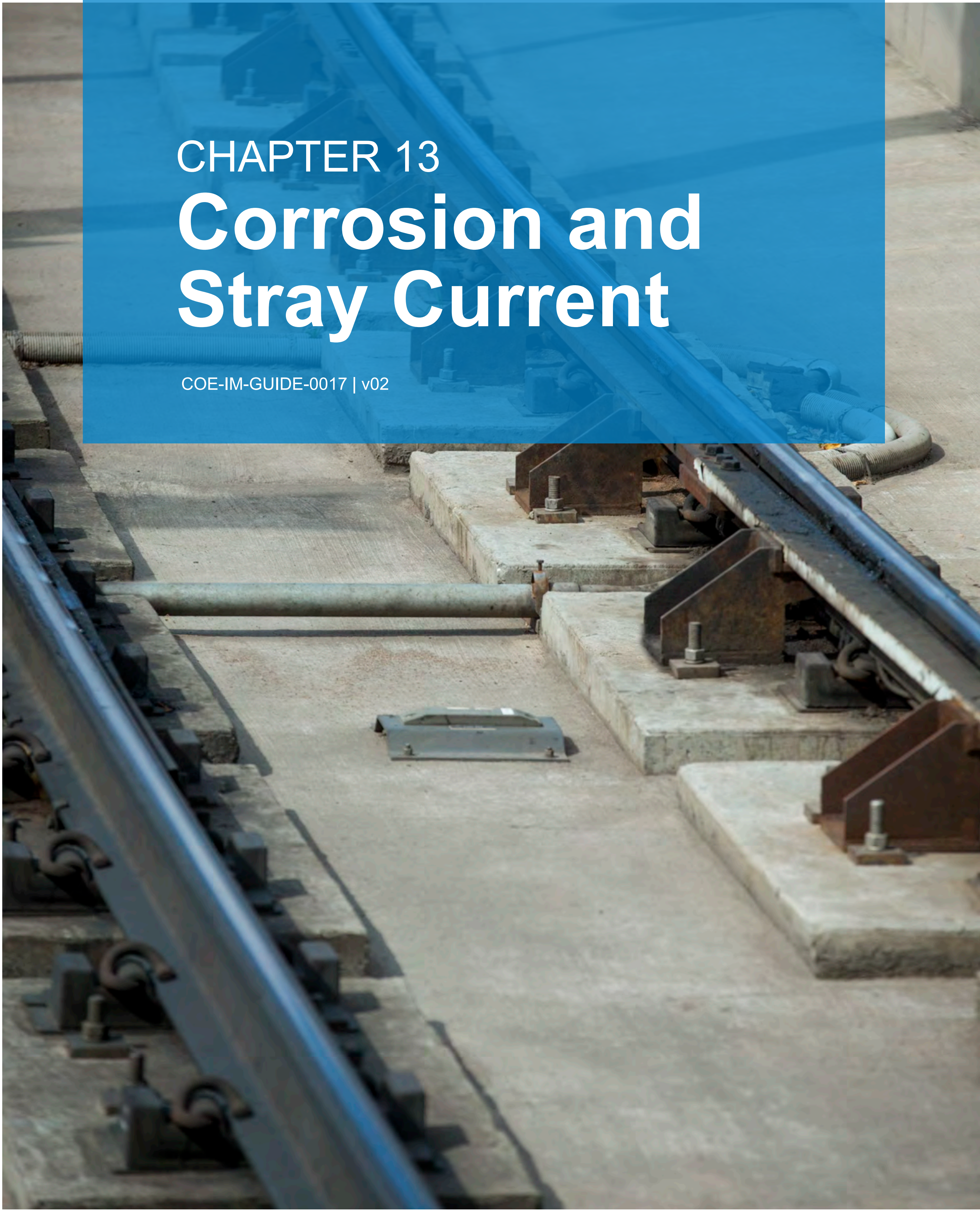

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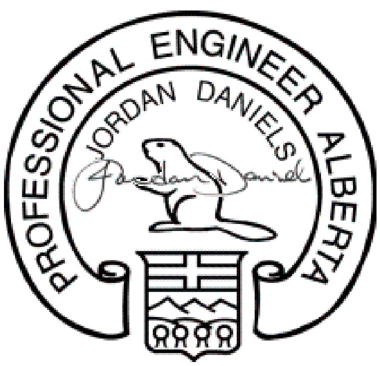

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13 CORROSION AND STRAY CURRENT

13.1 INTRODUCTION

This chapter presents guidelines related to corrosion and Stray Current control to minimize Stray Current leakage and prevent premature corrosion failures of Light Rail Transit (LRT) infrastructure, including surface structures, above ground and below ground structures, and facilities and structures adjacent to or crossing the LRT Right-of-Way (ROW).

There are two sections in this chapter. The first section provides a description of soil corrosion and potential control measures. Soil corrosion control measures are required to mitigate corrosion caused by soil/rock and groundwater. The second section provides a description of Stray Current and potential control measures. Stray Current control measures are required to limit Stray Current to acceptable levels. All designed soil corrosion and Stray Current control systems should be economical to install, operate, and maintain.

To effectively identify and mitigate corrosion and Stray Current issues, multi-disciplinary coordination is required during preparation of the Design. LRT projects must include documentation to verify that the appropriate corrosion control measures are implemented in the Design as provided in this chapter. The two main documentation requirements are a Stray Current Survey and a Stray Current Mitigation Plan, which are provided in this chapter. These documents must be project specific, identify corrosion and Stray Current issues, and describe how the Design mitigates the identified issues.

13.1.1 Purpose

Application of this chapter is intended to meet the following objectives:

- Realize the design life of system facilities by avoiding premature failure caused by corrosion
- Provide continuity of operations by reducing or eliminating corrosion related failures of systems and subsystems
- Minimize annual Operating and Maintenance (O&M) costs associated with material deterioration
- Minimize detrimental effects on adjacent privately-owned facilities and Conductive Structures that may be caused by stray current from LRT operations

13.2 APPLICABLE CODES, STANDARDS, AND REGULATIONS

All design of soil corrosion and Stray Current control must meet or exceed the requirements of the latest versions of codes and standards indicated below. This list is not exhaustive; all other relevant codes, standards, and regulations must be considered in the Design.

- Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing [221]
- Standard Test Methods for Chloride Ion in Water [222]
- Standard Test Method for Sulfate Ion in Water [223]
- Standard Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate [224]
- Guide to Design and Construction Practices to Mitigate Corrosion of Reinforcement in Concrete Structures [225]
- Protection of Metals in Concrete Against Corrosion [226]
- Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete [227]

- Standard Practice for Determining Rail-to-Earth Resistance [228]
- Cathodic protection of buried or immersed metallic structures. General principles and application for pipelines [229]
- Railway applications - Fixed installations - Electrical safety, earthing and the Return Circuit Part 1: Protective provisions against electric shock, and Part 2: Provisions against the effects of Stray Currents caused by DC traction systems [230]
- Protection against corrosion by Stray Current from direct current systems [231]
- Control of Electrochemical Corrosion of Underground Metallic Structures [232]
- Maintenance and Rehabilitation Considerations for Corrosion Control of Atmospherically Exposed Existing Steel-Reinforced Concrete Structures [233]
- Corrosion Management of Atmospherically Exposed Reinforced Concrete Structures [234]
- Sacrificial Cathodic protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures [235]
- Impressed Current Cathodic protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures [236]
- SP0315/IEEE Std 1835-SG: Standard for Atmospheric (Above Grade) Corrosion Control of Existing Electric Transmission, Distribution, and Substation Structures by Coating Systems [237]
- Cathodic protection of Reinforcing Steel in Buried or Submerged Concrete Structures [238]
- Detection and Mitigation of Stray-Current Corrosion of Reinforced and Prestressed Concrete Structures [239]
- ASTM G165-99 – Standard practice for determining rail-to-earth resistance [240]
- NACE SP0169- Control of External Corrosion on Underground or Submerged Metallic Piping Systems [241]
- CSA 22.1: – Canadian Electrical Code, Part 1 [42]
- CSA 22.2 No. 41 – Grounding and Bonding Equipment [242]
- CENELEC - EN 50122-1 Railway applications - Fixed installations - Electrical safety, earthing and the Return Circuit - Part 1: Protective provisions against electric shock [243]
- EN 50162 Protection against corrosion by Stray Current from direct current systems [244]
- ASTM G162-18: Standard Practice for Conducting and Evaluating Laboratory Corrosion Tests in Soils [245]
- AASHTO R 27: Standard Practice for Assessment of Corrosion of Steel Piling for Non-Marine Applications [246]
- NACE Publication 24255: Direct Current Operated Rail and Transit Stray Current Mitigation [247]
- AWWA Standards: Pipe and Accessories [248]
- NACE Publication 01110: Stray-Current Corrosion in Reinforced and Prestressed Concrete Structures [249]
- ISO 12944-2: Paints and Varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments [250]
- ISO 9223: Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination, and estimation [251]
- ISO 9224: Corrosion of metals and alloys – Corrosivity of atmospheres – Guiding values for the corrosivity categories [252]

13.3 SOIL AND WATER CORROSION CONTROL

This section provides guidelines for the design of systems and measures to prevent corrosion of Conductive Structures due to contact with soil, rock, and groundwater.

Design of Conductive Structures should be based on achieving the service life stated in Chapter 1, General and Chapter 9, Structures. This includes protection from environmental conditions by using coatings, insulation, cathodic protection, electrical isolation, electrical continuity, or a combination of methods as appropriate. The design of corrosion control systems should be based on geotechnical testing in areas of below-grade construction, including an analysis of soil/rock resistivity, moisture content, pH, chloride and sulfate ion concentrations, and presence of sulfides.

13.3.1 Application of Corrosion Control

Corrosion control protection is required for Conductive Structures where degradation of the structure due to corrosion may affect its safety or interrupt the continuity of LRT operations. Prior to the design of corrosion control protection, the corrosivity of the soil at the location of the structure must be assessed through industry standards. Consideration must be given to locations that may be subject to external corrosive agents, and how new assets will affect corrosivity. For example, road crossings and tunnel portals where structures will be exposed to road salts and how the salt-water runoff will propagate through the tunnel must be assessed. All permanent test facilities must be accessible by service personnel after installation to allow for periodic maintenance and monitoring.

Design of corrosion control measures for Conductive Structures owned by others, but required as part of an LRT project, should be coordinated by Designer with the owner of the Conductive Structure. The Design must minimize impacts on LRT System elements and on third-party owned Conductive Structures.

13.3.2 Materials and Methods

13.3.2.1 Coatings, Poly Bags, and Shrink Sleeves

Material selection, surface preparation, and Quality Assurance/ Quality Control (QA/QC) of coatings, poly bags, and shrink sleeves (‘coatings’) is critical for protection of metallic pipes and must be fully defined in comprehensive coating specifications. Surface preparation must be to Society for Protective Coatings (SSPC) /NACE requirements, and a coating contractor must provide evidence of certification to SSPC QP 3 – Shop Painting Certification Program and coating QA/QC undertaken by NACE certified coating inspectors. For critical assets an independent NACE certified inspector should be engaged.

Application of coatings should be at the mill wherever practicable, with field application of a compatible paint or tape system. Contractors responsible for applying the coatings must have the appropriate qualifications, with QA/QC completed by a NACE certified coating inspector. Coating systems must have minimum life expectancies of 15 years prior to major maintenance or reapplication. Products must have established performance records for the intended life expectancy and be compatible with the base metal to which they are applied.

Finishes must have demonstrated tolerance to handling damage and compatibility with designed cathodic protection systems (i.e. resistant to cathodic disbondment).

13.3.2.2 Insulation

Devices used for electrical insulation for corrosion control include non-metallic inserts, insulating flanges, couplings, unions, and/or concentric support spacers that meet the following criteria:

- Mechanical and temperature ratings must be equivalent to the structure in which they are installed
- Devices (except non-metallic units) buried in soil must be encased in a protective coating
- Devices (except non-metallic units) installed in chambers or otherwise exposed to partial immersion or high humidity must have a protective coating applied over all components

- Inaccessible insulating devices, such as buried or elevated insulators, must be equipped with accessible permanent test facilities

13.3.2.3 Bonds

Bonds must be installed to ensure electrical continuity for all non-welded metallic pipe joints. Bonds must be sized based on electrical characteristics of the conductive structure and resulting electrical network to minimize attenuation and allow for cathodic protection. A minimum of two Bonds must be provided per joint for redundancy. Galvanic corrosion resulting from physical contact of different metals must be addressed in the Design and specifications for all bonds.

13.3.3 Utilities and Underground Conductive Structures

Protective measures to be considered for utilities and underground Conductive Structures are described below.

When practicable, parallel and crossing utilities should be non-conductive material. Engineering analyses must be completed to confirm non-conductive utility crossings can withstand expected static and dynamic loads. When metallic utility crossings are required, either as a casing for additional mechanical strength or because a non-conductive crossing is not practicable, the Design must consider sacrificial anodes and test stations to protect the crossing and provide a means of assessing its health.

13.3.3.1 Ferrous Piping

All new buried ferrous piping, including cast iron, ductile iron, and steel piping must have cathodic protection.

13.3.3.2 Copper Piping

Buried copper pipe must be electrically isolated from non-buried piping, structural elements, and buried pipe of other metals that may be subject to galvanic corrosion when in contact with copper pipe. Insulators must be accessible for maintenance and must not be buried.

13.3.3.3 Buried Concrete/Reinforced Concrete Structures

Design of cast-in-place concrete structures, standard precast components such as vaults or manholes, and segmented concrete rings should be in accordance with applicable local codes, regulations, and standards.

No special corrosion control measures are required for shotcrete applications that do not provide permanent structural support.

13.3.3.4 Support Piles

The following is applicable to support piling systems which provide permanent foundation support.

Concrete-filled steel cylinder columns, where the steel is an integral part of the load bearing structure, should be designed considering the need for special corrosion control measures, such as sacrificial thickness, an external coating system, and/or cathodic protection. These Designs must be determined based on type of load bearing structure, corrosive soil characteristics, exposure to chlorides, and the degree of anticipated structural deterioration caused by corrosion.

Piles used for temporary support do not require corrosion control provisions.

13.3.3.5 Reinforced Concrete Retaining Walls

Corrosion control is required for modular soil-steel retaining walls with structural support components beneath the Trackway.

13.4 STRAY CURRENT CONTROL

This section provides guidelines to minimize the corrosive effect of stray current from LRT operations on Conductive Structures.

Stray current is a random current that leaves the negative return circuit and follows unintended parallel electrical paths through the trackwork component, ground soil (acting as an electrolyte), and/or other Conductive Structures prior to returning to the rails and the rectifier negative terminal at the Traction Power Substations (TPSS).

The magnitude of stray current is affected by the distance between TPSS. Greater distances between TPSS lead to higher current through the negative return circuit and lower resistance between the negative return circuit and ground due to the increased number of parallel paths. Stray current magnitude must be considered when determining the maximum spacing between TPSS. Refer to Chapter 6, Traction Power for additional information.

The rate of stray current corrosion is a function of stray current intensity. Typical dissolved metal quantities per Ampere of stray current during one year of operation are:

- Aluminum: 2.90 kg or 1,080 cm^3
- Iron: 9.13 kg or 1,160 cm^3
- Lead: 33.80 kg or 3,000 cm^3
- Copper: 21 kg or 2,360 cm^3

The objective of Stray Current control is to reduce or limit the level of Stray Current at the source, under normal operating conditions, rather than trying to mitigate the corresponding, possibly detrimental, effects which may otherwise occur on Conductive Structures. The high-level design goals to limit Stray Current at the source are:

- Provide high resistance between the return circuit and the soil through the use of resistive rail boots, polymers, sleeper pads, insulated fasteners, etc., and by eliminating direct and indirect connections between the negative return rail and ground
- Provide a low resistance return circuit through the use of rail cross-bonds and multiple return cables to the TPSS
- Minimize Stray Current during normal revenue operations through design of the Traction Power System (TPS) as provided in Chapter 6, Traction Power

13.4.1 General Documentation Requirements

The Designer must develop a Stray Current Mitigation Plan and a Stray Current Survey to support the Design.

13.4.1.1 Stray Current Mitigation Plan

The Stray Current Mitigation Plan must establish Stray Current control requirements, identify the infrastructure to be considered in the Stray Current Design, and provide verification and validation requirements.

At a minimum, the Stray Current Mitigation Plan must:

- Describe the management and coordination of Stray Current and corrosion control

- Identify, and provide an analysis supporting the selection of, specific industry standards and best practices that will be applied to the Design of Stray Current control, including:
    - Maximum acceptable Stray Current levels required for the LRT System and equipment to operate safely and reliably
    - Identification of testing requirements and acceptable test levels for verification and validation of the Stray Current Mitigation Plan at the time of installation and during normal operations
- Define Design techniques and protective provisions to be implemented in the Design to minimize the amplitude and mitigate the effect of Stray Current
- Identify the residual Stray Current that Conductive Structures will be exposed to following implementation of Stray Current mitigation measures and any additional Design or operational measures required to achieve the design service life
- Identify the surveys, testing, and test methods that will be used to verify and validate the mitigation provisions
- Identify locations of test facilities for monitoring Stray Current and rail to ground resistance during LRT operations

13.4.1.2 Stray Current Survey

The purpose of the Stray Current Survey is to establish a baseline for the prevailing Stray Current prior to construction of the LRT project. Potential sources of stray current are operating Direct Current (DC) LRT lines, and other systems that may generate a ground return current (e.g. impressed cathodic protection systems, and power distribution and transmission lines). Once the project is in operation, the Stray Current Survey will determine the impact of the project on Stray Current levels.

At a minimum, the Stray Current Survey must:

- If applicable, establish a pre-project Stray Current baseline for the project area(s), as follows:
    - Determine through calculations or measurement, existing Stray Current, grounding characteristics, and (if applicable) touch potentials for sensitive interfaces, such as:
        - Traction Power Substations (TPSS)
        - The positive and negative distribution system, including rail-to-ground resistance
        - Cross Bonds and track insulation
        - Stray Current leakage path controls
        - Grounding systems
        - At-Grade and elevated guideways
        - Maintenance facilities
        - Adjacent Conductive Structures, utilities, and pipelines (Note: this process would be through identification of impacted stakeholders for baseline studies and/or access to measure stray current sources on adjacent properties)
    - Determine through calculation or measurement, the existing leakage current characteristics that have the potential to interfere with sensitive Train equipment.
- Complete post-project Stray Current calculations and measurements inclusive of the implemented Stray Current mitigations for the project area.
-
- Compare the post-project Stray Current to the pre-project baseline (if applicable) and the Design levels defined in the Stray Current Mitigation Plan.

13.4.2 Stray Current Design

13.4.2.1 General Design Provisions

To reduce possible effects of Stray Current, adequate mitigation techniques must be applied. Mitigation techniques must be identified in the Stray Current Mitigation Plan. Stray Current designs shall primarily focus on mitigating Stray Current at the source by providing a low-resistance negative return system that has a high resistance to ground. In areas where a high resistance to ground cannot be achieved, additional mitigation measures must be explored to protect adjacent conductive structures.

13.4.2.2 Stray Current Monitoring Facilities

TPSS design must allow for remote monitoring of the rail to ground voltage and/or the Stray Current return through either the rail to ground switch or a dedicated test facility at the TPSS.

13.4.2.3 Provision of Test Locations

Stray Current control design must include test points to verify that the rails are insulated from ground and to detect any leakage of Stray Current during LRT operations. Test locations must be easily accessible by maintenance staff and must be provided at strategic locations to isolate Stray Current sources. Test locations will be affected by the type of Signaling system and the placement of Insulated Joints, and therefore must be coordinated with the Signals and TP Design.

13.4.2.4 Isolation of Conductive Structures

To reduce Stray Current effects, the total resistance between Stray Current sources and other Conductive Structures should be increased as much as reasonably practicable. Design should assess increasing resistance by one or more of the following methods:

- Avoidance of direct contact between Stray Current sources and other Conductive Structures that may be affected by Stray Current
- Use of materials with high resistivity for isolation of the track
- Use of protective coatings to increase resistance between Conductive Structures and surrounding soil
- Locating Conductive Structures as far as practicable from identified Stray Current sources

13.4.2.5 Level crossings

The conductance per unit length between DC negative circuit and ground at level crossings must not exceed the value of the neighbouring tracks when running rails are in embedded track. Rail boots or insulating grout shall be used for embedded track at level crossings to insulate the rail from the surrounding track structures.

13.4.3 Traction Power System

Refer to Chapter 6, Traction Power, for design guidelines for the LRT TPS including TPSS, Power Distribution System (PDS), and the Overhead Contact System (OCS). The Edmonton High Floor LRT System implements a 700 V Traction Power System, with a floating (ungrounded) negative return circuit. High-resistance track pads, rail boots, and grout are used to limit the stray current from rail to nearby Conductive Structures.

13.4.3.1 Traction Power Substation (Mainline)

TPSS Design must allow for monitoring of the rail to ground voltage and for connection of the negative bus to the substation ground grid through a normally open rail to ground switch/contactor. The Design must allow for remote monitoring of the rail to ground voltage and/or the Stray Current return through either the rail to ground switch or a dedicated test facility at the TPSS.

The Stray Current monitoring system should include either a stand-alone data acquisition module and communications package or a Supervisory Control and Data Acquisition (SCADA) interface for remote monitoring. Necessary space and conduits for Stray Current monitoring, including future expansion requirements, must be included in the facility Design.

13.4.3.2 Positive Distribution System

Stray Current generated from the positive distribution system is small compared to that generated from the negative Return Circuit. OCS, consisting primarily of support poles, catenary support hardware, contact wire, and where applicable, messenger wires, must be designed to minimize generation of Stray Current. Design of the OCS must provide electrical continuity between support poles and foundation reinforcing steel to dissipate Stray Current generated by the positive distribution system.

On elevated structures, OCS support poles must be connected to the structure ground electrode system, if available. If the elevated structure does not include a ground electrode system, the OCS support poles must be connected to the nearest collector bar.

13.4.3.3 Mainline Negative Return System

A reliable and service-proven low resistance negative return system with adequate isolation from ground is essential for Stray Current control. Designs should consider Continuous Welded Rail (CWR), impedance Bonds, low resistance rail joint Bonds, or a combination of the three at mechanical joints in the rails to maintain a low resistance negative return system. To further reduce the Return Circuit resistance, the Design must consider rail and track Bonds and Cross Bonds.

Mainline rail, including special Trackwork, At-Grade crossings and all ancillary system connections, must be designed to have a minimal, uniformly distributed, in-service rail to ground conductance and must ensure insulation quality of the rails toward ground will not be diminished substantially by water. Trackway drainage must be designed to drain standing water from the tracks. Refer to Chapter 16, Utilities and Drainage for drainage requirements.

All dead-end tracks must have isolation joints installed to isolate bumping posts and other similar devices that are electrically grounded.

Tie and ballast track design must specify clean, high-resistivity ballast material with adequate drainage, grading, and appropriately designed insulating track fastening devices, such as insulated tie plates, direct fixation fasteners or other methods accepted by the Engineer, to maintain the resistivity of the ballast during operation. The top of the ballast material should be minimum of 25 mm below the bottom of all metallic surfaces. The ballast specification must include the required resistivity of the ballast, and testing requirements to verify the provided ballast meets the specified resistance for mitigation of stray current. Refer to Chapter 5, Trackwork for additional information.

For embedded track, an insulating resin bed or electrometric polymer, or provision of insulating intermediate layers between tracks and bearing systems, such as a rail boot, must be provided. Adequate drainage, both at the surface and at subgrade level, is required to prevent standing water that could compromise rail insulation. Refer to Chapter 5, Trackwork for additional information on track components, and Chapter 16, Utilities and Drainage for additional information on drainage requirements.

13.4.3.4 Isolation from Conductive Structures

Direct electrical connection between Conductive Structures and the Return Circuit must be avoided to prevent the risk of Stray Current exchange corrosion.

13.4.3.5 Isolation from Wayside Equipment

The Return Circuit must not have direct conductive contact with grounded equipment, including, but not limited to, switch machines, track blowers, rail greasing machines, Signaling devices, and Train communication devices.

All equipment with mechanical connections to rails must be electrically isolated from the rail, although the Designer may consider electrical isolation of equipment from ground to maintain integrity of the track-to-ground resistance.

13.4.3.6 Negative Return for Operation and Maintenance Facilities (OMF)

Yard Track must be electrically insulated from Mainline track and from ground. Within an OMF shop, a direct connection between the Return Circuit and ground is acceptable to create an equipotential zone for maintenance work.

13.4.4 Provisions for Tunnels, Bridges and Reinforced Concrete Track Slabs

Reinforced concrete structures, including tunnels, bridges, and reinforced concrete slabs are susceptible to the effects of Stray Current. The Stray Current Design must consider the impact of Stray Current on these structures through calculation of the voltage shift between the structure and ground during the highest traffic LRT hours per EN 50122-2, at minimum. The Designer must consult the current version of EN 50122-2 and any other relevant standards to determine the permissible voltage shift at the time of the Design.

In general, the Design should control Stray Current at the source to meet the permissible voltage shift on the structure. If this is not practicable, additional mitigation measures must be considered.

Soil conditions and environmental corrosivity should be evaluated to determine the need for application of a barrier coating. If soils are determined to be highly corrosive, the Design must include a coating in accordance with Section 13.3.2.1.

13.4.4.1 Section Isolation

Conductive LRT structures may be divided into longitudinal sections, with Insulating Joints to limit the voltage shift between the structure and the ground to acceptable levels. At ring joints between each section, provisions must be made for test purposes.

Provisions must be made at the at the Isolating Joint to prevent current flow across the Insulating Joint through the ground.

13.4.4.2 Additional Design Considerations

The designer must evaluate current codes and standards to determine applicable Stray Current mitigation measures for the unique requirements of the Design. These include, but are not limited to:

- Increasing the structure to ground resistance by specifying high-resistance materials for the foundations
- Use of non-conductive rebar (e.g. glass fibre reinforced polymer)
- Equipotential bonding of conductive rebar (typically wire wrapping is sufficient for bonding; refer to EN 50122 for additional information)
- Longitudinal interconnection through reinforcing bars, mats, other conductive structural parts, and if applicable, additional conductors

13.4.4.3 External Cables, Pipework, and Power Supply

On bridge structures and in underground structures, precautions must be taken to avoid stray current exchange between the structure ground and remote non-railway installations. At all entrances to metal reinforced concrete or metallic structures, all metallic pipe work, hydraulic lines, and cable sheaths, as well as connections to ground coming from outside the structure must be electrically separated from the structure ground to avoid conductive connections to external ground electrodes.

When necessary for safety reasons, every section of metal pipe may be connected to the structure ground.

13.4.5 Adjacent Pipes, Cables, and Utilities

13.4.5.1 Separation

The conductive parts of the DC traction system must be kept as far away from buried pipes, cables, and utilities as reasonably practicable. All existing pipes, cables and utilities within the limits provided in Chapter 16, Utilities and Drainage, and extending beneath and adjacent to the Trackway, must be replaced or relocated. If replacement or relocation is not practicable, the buried pipes, cables, and utilities must be evaluated as part of the Stray Current Mitigation Plan and the Design must minimize the effect of Stray Current.

13.4.5.2 Parallel Utilities

The Stray Current Mitigation Plan must evaluate the potential impact of Stray Current on utilities running parallel to the LRT and include measures to minimize the impact of ongoing LRT operations on these utilities, even when the parallel utilities are outside the limits provided in Chapter 16, Utilities and Drainage. The Designer must use professional judgement to identify the parallel utilities that are considered in the Stray Current Mitigation Plan.

13.4.5.3 PE/PVC Pipe Installation

Where practicable, existing metallic pipe material should be replaced with a non-conductance material, such as Polyethylene (PE) or Polyvinyl Chloride (PVC).

13.4.5.4 Sectioning

For Stray Current interference resulting in a change of structure to ground potential on a long structure such as metallic pipelines, the measures described in Section 13.4.5.1 may be used to divide the structure interfered by Stray Current into smaller sections. Electrical isolation may be achieved by installing isolating joints.

For pipes carrying a conductive electrolyte, precautions should be taken against possible internal corrosion on the pipe wall at the anodic side of an isolating joint. Internal linings should be considered in this situation.

13.4.6 Structures with Cathodic Protection

For Conductive Structures protected by cathodic protection, the cathodic protection system performance and acceptability of the Stray Current design must be evaluated by the Designer. Performance of the cathodic protection must meet applicable industry standards and consider the impacts of normal LRT operation.

13.4.7 Criteria for Stray Current Acceptance

At the time of the installation, testing must be undertaken as indicated in the Stray Current Mitigation Plan. Testing must be completed by a qualified individual familiar with the project-specific Stray Current Mitigation Plan and identified acceptance criteria.

CHAPTER 14

Urban Integration

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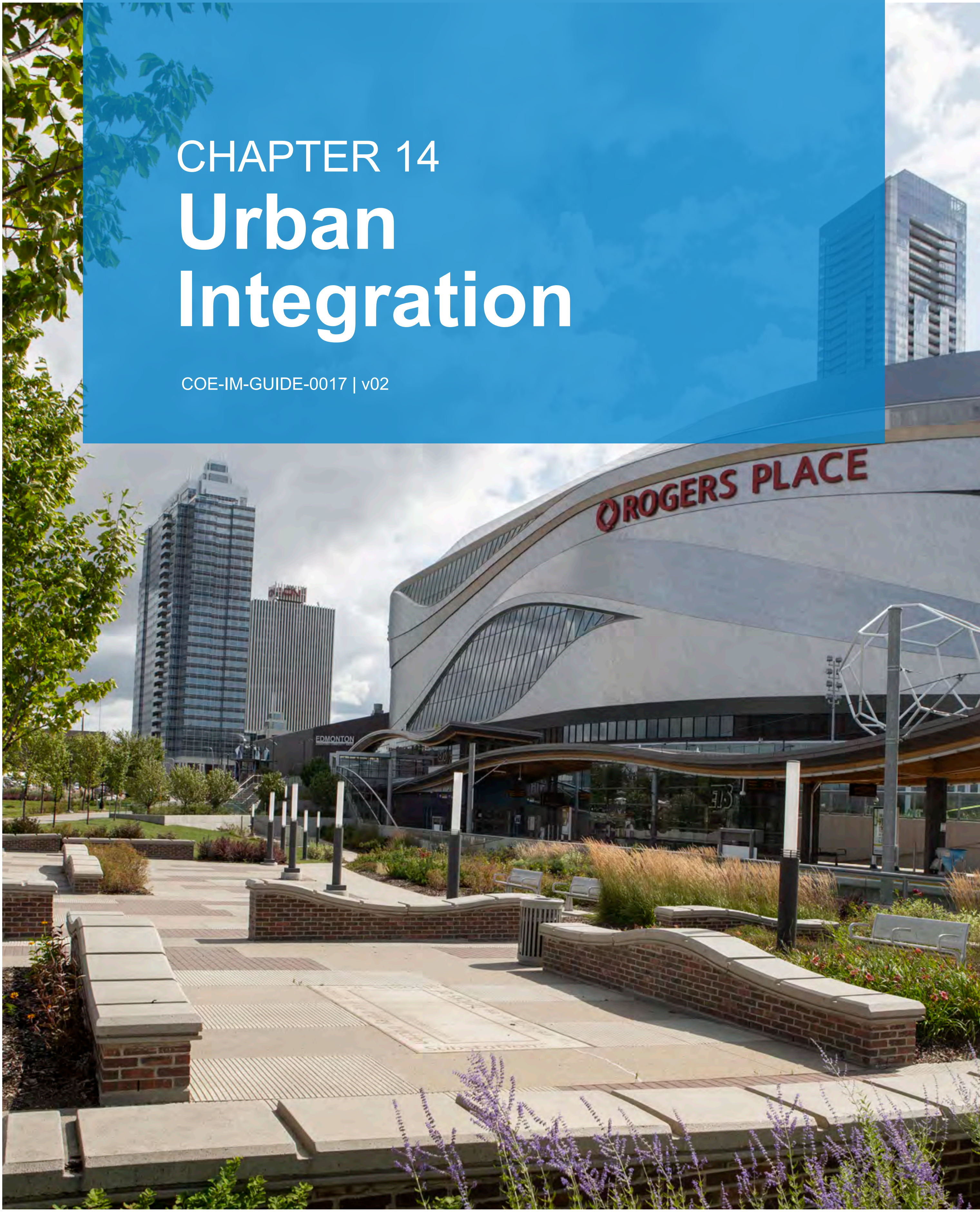

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INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

See complete Intent of Use Statement following the cover page.

14 URBAN INTEGRATION

14.1 INTRODUCTION

This chapter presents guidelines for the integration of Light Rail Transit (LRT) infrastructure into new and established communities. This includes the area adjacent to or impacted by the LRT and is more pronounced at Stations where additional Patron amenities, circulation requirements, or plaza areas are required. Guidelines are provided for Station area Accessibility and multi-modal connections, landscape design, noise and vibration control, Right-of-Way (ROW) delineation and barriers, and other Sustainable Urban Integration (SUI) elements affecting the surrounding environment.

14.1.1 Applicable Codes, Standards, and Regulations

14.1.1.1 Codes and Regulations Pursuant to the Safety Codes Act

- Alberta Building Code (ABC) [152]
- Alberta Fire Code (AFC) [176]

14.1.1.2 Policies and Bylaws

- City of Edmonton Community Standards Bylaw 14600 [79]
- City of Edmonton Urban Traffic Noise Policy C506 [253]
- City of Edmonton Zoning Bylaw 12800 [254]
- City of Edmonton, City Policy C602 Accessibility for People with Disabilities, Edmonton. (supersedes C463, C466 and the Edmonton Transit System (ETS) Accessible Transit Instruction) [255]
- City Policy C458C Percent for Art to Provide and Encourage Art in Public Areas [9]
- City Policy C573A Complete Streets [181]
- City Policy C565 Transit Oriented Development [182]

14.1.1.3 Design Standards and Guidelines

- Complete Streets Design and Construction Standards (CSDCS) [256]
- City of Edmonton Design and Construction Standards (D&CS) [257]
- City of Edmonton Transit Oriented Development Guidelines [23]
- Crime Prevention Through Environmental Design (CPTED) Principles [198]
- City of Edmonton Access Design Guide [258]
- City of Edmonton Wayfinding Design Standards, 2016 [259]

14.2 LRT RIGHT-OF-WAY DELINEATION

14.2.1 Application of Transportation Corridor and Operations Matrix

The Transportation Corridor and Operations Matrix provided in Chapter 1, General identifies three categories of Transportation Corridor delineation. Hard barriers are intended to prevent both intentional and inadvertent access to the Trackway by pedestrians, cyclists, and motor vehicles. Soft barriers are intended to limit inadvertent access to the Trackway. Curb delineation allows for authorized access to or across the LRT ROW where the Trackway is bordered by roadway or sidewalk curbs.

14.2.1.1 Hard Barrier – Exclusion

Hard barriers for vehicle exclusion should be Alberta Transportation TL-4 single slope concrete barriers [260] or concrete walls designed for vehicle impact. The addition of pedestrian exclusion fencing to the vehicle barriers should be considered in areas of high pedestrian activity, such as schools or shopping malls, and in proximity to Stations. In areas where adequate space exists between vehicle travel lanes and the Trackway, vehicle barriers may not be required. However, an assessment of the need for pedestrian exclusion fencing in these areas must be undertaken by the Designer. Appropriate setbacks from vehicle travel lanes to hard barriers are provided in Chapter 17, Streets.

14.2.1.2 Soft Barrier – Delineation

Soft barriers must be designed to provide visual and tactile warning of the presence of the Trackway to pedestrians, cyclists, and motorists. Some degree of exclusion may also be provided by the soft barrier depending on the type of treatment chosen. Soft barriers will generally be less visually intrusive than hard barriers but must provide clear delineation of the Trackway. Methods of creating soft barriers include chain and bollard type fencing, low walls, densely planted shrub beds, and raised planters. Snow clearing and snow storage requirements for both the LRT ROW and the adjacent Street elements must be considered in the design of soft barriers, as well as the impact of vegetation maintenance activities on LRT operations.

14.2.1.3 No Barrier – Limited Access

Roadway curbs in areas where access onto or across an embedded Trackway by emergency services is required must be semi-mountable (CSDCS Standard Drawing 5023). Potential misuse of Trackway access by non-authorized motor vehicles and pedestrians in areas with no barriers must be considered by the Designer in consultation with the Operator and emergency services providers. Maintenance access to the Trackway must be coordinated by the Designer in consultation with the Operator, particularly at track crossover or turnout locations.

14.3 SITE DESIGN AND NEIGHBOURHOOD INTEGRATION (URBAN INTERFACE)

An Urban Style LRT design philosophy aims to enhance and promote active and transit modes for travel in Edmonton. The Designer must identify opportunities to improve access and connectivity within and between all travel modes. New or renovated LRT infrastructure must achieve an optimal fit and integration with its surroundings by using Station designs and waiting amenities that are appropriately scaled to the surrounding urban realm, while considering anticipated ridership, adjacent land uses, and the intended mode of operation for the LRT segment.

The Designer must consider opportunities to provide an accessible, safe, and convenient pedestrian realm where the LRT ROW and Stations intersect adjacent roads, sidewalks, and bicycle networks.

The following sections provide general guidance on integrating Stations and pedestrian amenities into the surrounding urban realm.

14.3.1 Intersection Nodes

Trackway alignment may be either side or centre running within the Transportation Corridor. These two alignments require distinctly different approaches to the design of pedestrian access to the Station node, although in both cases it is the pedestrian crossings in the adjacent intersections that serve as the main entry points to the Station. These crossings also act as the gateway from the LRT to the surrounding urban realm and communities beyond the node. The scale and function of these intersections must be carefully balanced between vehicular movement and traffic management, and Patron movements.

For elevated or tunneled Grade Separated Stations, this relationship is less dependent on nearby intersection function. However, for most trench-style Grade Separated Stations, this relationship remains an important node feature. The Designer must consider intersection crossings from the standpoint of Barrier-Free pedestrian comfort and safety whether related to the need for queueing and refuge space, or the paving materials, curbs, bollards, and crossing control elements that help to delineate and define them.

Intersections nearest to Stations are, typically, the most important connecting element in an Urban Style system, where private vehicle, transit, and active modes of urban mobility are integrally linked.

Intersection design at or near Stations should create active and transit mode connectivity, within and beyond the Station node while maintaining the safe and efficient movement of motor vehicles through it.

The primary function of a pedestrian crossing through an intersection next to a Station is to provide safe, Barrier-Free access between the Platform and the surrounding community.

14.3.1.1 Mid-Block LRT Crossings

Due to their length, it may be challenging to integrate Platforms in a manner that does not create a physical or visual barrier to access within the corridor or between portions of the surrounding community served by the node. With safety a paramount consideration, mid-block crossings can provide a second point of access to and egress from the Platform end furthest from an intersection while also improving overall neighbourhood connectivity along the adjacent Transportation Corridor. Proposed mid-block crossing locations must be reviewed by the Engineer and will be subject to further study and risk assessment.

14.3.1.2 Amenity Zones

Amenity zones are places within an intersection node or immediately adjacent to a Station plaza where essential off-Platform Patron amenities are provided. Depending on the proximity, complexity, and frequency of other transportation modes and services, amenity zones must be designed in ways that safely accommodate and effectively integrate these important connections.

The design of amenity zones should include consideration for the following elements:

- Waiting and rest amenities with seating, pedestrian wayfinding and signage, waste and recycling receptacles, and pedestrian-scaled lighting
- Landscaping
- Shared Use Path (SUP), cycle track and bike lane connections
- Bicycle amenities such as secure bike storage, shelters, and repair facilities
- Connections to bus transit
- Patron Drop-Off and pick-up areas for Kiss and Ride, taxi, and ride-share services
- Programmable space for street vendors or food trucks
- Public art
- CPTED-supporting elements [198]
- Security (Closed Circuit Television (CCTV) and help phones)

14.3.1.3 Plaza Areas

Station plazas, as an extended or more formal type of amenity zone, are focal points that must be scaled and appointed in a way that can accommodate other urban design objectives owing to their unique community setting or regional importance. These other objectives may be related to statutory zoning and land use planning requirements, the presence of nearby recreational or cultural centres, or an urban setting where the scale and public stake in the space go beyond the LRT functionality.

Opportunities to create plaza areas should be considered wherever practicable to create Stations that are better integrated into their surrounding context.

In a center-running, side-loading configuration where buildings are set back from the edge of the corridor, or where an adjoining or abutting business frontage runs parallel to the Station, the Platform can be integrated as an extended sidewalk or forecourt.

Where existing grade differences allow, the finished height of new, adjoining plazas can be extended and seamlessly integrated at the elevation of a Platform.

In a side-running, side-loading configuration where a Platform abuts a pedestrian or active-mode environment and where significant differences in plaza/Platform elevations exist the Designer should consider opportunities to exploit these grade differences through stairs, sloped sidewalks, ramps, and terraced retaining and planting structures.

In all instances, the amenities listed in Section 14.3.1.3 should be considered in plaza design.

14.3.2 Accessibility

14.3.2.1 General Principles

Accessibility, as an overarching goal of sustainable integration, is a fundamental precondition to connecting Patrons to the LRT System. The Design must accommodate the needs of all persons regardless of their physical, sensory, and cognitive abilities and must consider the convenience, ease of use and comfort for Patrons as complementary elements.

At minimum, all ETS owned and operated facilities that are publicly accessible must be designed as Barrier-Free spaces, meeting the requirements of the ABC [152] and the Alberta Barrier Free Guideline [261]. However, in accordance with the City's Corporate Accessibility Policy C602, the designer must reference and apply the more stringent guidelines presented in the City of Edmonton's Access Design Guide [258]. These requirements apply to the design of all exterior pathways and connections between LRT facilities, Transit Centers, dedicated drop off zones, and other public amenities that are part of the Design. Refer to Chapter 1, General for further information.

14.3.2.2 Exterior Accessible Routes

All public, active-mode, exterior access routes such as sidewalks, ramps and pathways must be designed to be Barrier-Free and include Universal Design features.

The Design must include appropriate infrastructure and technologies to support multi-modal interchanges. Bus stops, Patron loading zones, and paratransit zones near the Station must be provided. Barrier-Free pathways to replacement bus service stops must also be provided. The Designer must confirm the locations for and operation of replacement bus services with the Operator.

Paved surfaces, including at all pedestrian crossings of Streets and Trackways, must be slip resistant and not hinder or impede users who travel with wheeled mobility aids, canes, or strollers. Refer to material finish requirements provided in Chapter 10, Stations and Ancillary Facilities.

Guidance Tactile Walking Surface Indicators (TWSI) must be provided where practicable with due consideration given to their ease of use in relation to the materials and textures of the adjoining or abutting paved pedestrian surfaces. Though standards are still evolving, guidance TWSI must also be used to provide directional wayfinding where practicable between Stations and Transit Centers, dedicated drop off zones and nearby bus stops.

Wayfinding or other signage with raised lettering or other communication devices must be provided as appropriate for the location while adhering to the ETS Brand Guide and ETS Signage Design Guidelines, Part I-6 of the latest City of Edmonton Access Design Guide [258], as well as the City of Edmonton Pedestrian Wayfinding Design Standards.

The Designer must consider sight lines at nodes, pathways, and plazas to allow people using active modes of transportation to clearly identify the route to Stations and their surrounding facilities. The principles of CPTED must also be applied. Refer to Chapter 15, Safety and Security.

14.3.3 Multi-Modal Stations

Multi-Modal Stations help maximize accessibility and use of the LRT System. These interchanges allow Patrons to arrive and depart Stations through a variety of modes. Interchange functions require their own set of design considerations.

Certain multi-modal interchanges, such as paratransit drop-off and pick-up, must meet specific requirements. The Designer must consult the Operator and Engineer on the necessary infrastructure to meet the specific needs of the interchange. The Designer should also recognize unique opportunities at interchanges where ease of use and comfort can be further promoted and integrated.

14.3.3.1 Paratransit Vehicle Loading Zones

The allocated paratransit area should provide for side and rear loading/unloading operations from a vehicle, including persons in wheelchairs. Most vehicles transporting persons with disabilities are equipped with side loading devices.

A lay-by designated for paratransit vehicles should be provided where Kiss and Ride drop off areas are designed. Where Kiss and Ride zones are not provided, paratransit vehicle loading areas must be provided near Station access points.

14.3.3.2 Kiss and Ride Zones

Areas may be designated as drop-off and pick-up zones for Kiss and Ride and taxi or other for-hire vehicle services.

In the absence of defined standards governing curbside space, the Designer must give careful consideration to providing enough curbside space and associated circulation area to meet the anticipated demand of ride-sharing and ride-hailing services.

The Design of the curbside area should accommodate Patrons waiting for extended periods of time. Signage and wayfinding must be provided to help direct both Patrons and motorists to the pick-up and drop-off location.

The Designer should consider added Patron waiting and safety amenities based on anticipated peak volumes of Patron pick-ups, wait times during off-peak LRT service, exposure to the elements, and non-daylight hours of operation.

14.3.3.3 Shared Use Path and Cycle Track Connections

SUPs must be connected to and integrated with all Urban Style Stations. Appropriately scaled and located amenities should be incorporated into the design of SUP connections to support the transition between the SUP, the Station, and any associated amenity zones. Where designated cycle track facilities exist or are planned within the Transportation Corridor, their operational impacts must be fully evaluated and understood so that they can be safely and effectively integrated with all elements of the LRT ROW and intersecting or parallel-running Streets and Station access points. Stations should also be equipped with ample and secure bicycle parking that is easily seen from the nodal hub, well-lit, and near the Platform. Refer to Section 14.3.4.2.

14.3.3.4 Park and Ride Facilities

Where Park and Ride facilities are provided at Stations, access routes between facilities must be safe and accessible. Refer to Section 14.3.3.2 for additional information. Refer also to Chapter 10, Stations and Ancillary Facilities for guidelines on Park and Ride facilities.

14.3.3.5 Transit Centre Plaza and Other Bus Connections

Stations may be paired with ETS Transit Centres at designated high-ridership areas or where key intermodal connections are required. Both Transit Centres and on-street bus stops must be designed and located to facilitate integration between facilities. This will provide a coherent and high-quality Patron experience and support a shift from motor vehicles to transit and active modes.

Refer to the ETS Transit Centre Guideline for further information.

14.3.4 Site Amenities, Furniture, and Equipment

14.3.4.1 Furniture

The type and placement of street furnishings must be considered in conjunction with the adjacent urban context and the Platform. This is especially true at Station areas where adjacent amenity zones have been designed to reinforce Station access routes, intersection nodes, multi-model connections, and other plaza areas.

Refer to the Complete Streets Design and Construction Standards [256] for more information

14.3.4.2 Bicycle Amenities

Robust bicycle infrastructure must be provided in the area surrounding each Station to promote and support mode shift and to reinforce multi-modal connectivity. At a minimum, secure bicycle racks must be provided at Stations. Quantities and types of bicycle amenities must be based on the projected ridership for the Station, provision of other multi-modal connections, and the surrounding land uses. Depending on the site context, enhanced or additional amenities may be incorporated into the design of bicycle infrastructure, including:

- Secure bicycle racks
- Bicycle shelters
- Bicycle repair facilities
- Bike-share areas for docked or dock-less bikes and/or scooters

Refer to the City of Edmonton Bike Plan for further information on bicycle parking facility design.

14.3.4.3 Signage and Wayfinding

Signage and wayfinding must be effective in guiding Patrons to the Platform without adding unnecessary visual clutter or obstructions to safe and convenient travel through or past Station nodes. Wayfinding should be present along all access pathways including sidewalks, plazas, SUPs, and cycle tracks and from transit connections and destinations in the local area. Refer to Chapter 10, Stations and Ancillary Facilities for further information. Wayfinding or other signage should be provided with raised or recessed tactile lettering, braille, or other communication devices appropriate for the location while adhering to the ETS Brand Guide, Part I-6 of the latest City of Edmonton Access Design Guide [258], as well as the most current versions of the ETS Signage Design Guidelines and City of Edmonton Pedestrian Wayfinding Design Standard [259].

14.4 LANDSCAPING

This section provides guidelines for the landscaping design of areas within and adjacent to the LRT ROW. Landscaping includes trees, shrubs, groundcover, grasses and planting beds. Landscaping may be placed in the Urban Interface zone, roadway medians, verges, and boulevards, Station amenity zones, and plaza areas. Landscaped areas within the Trackway are not permitted.

14.4.1 Landscape Setbacks

Landscape plantings in the LRT ROW must conform to the setbacks described in the City of Edmonton Design and Construction Standards (D&CS) and the Complete Streets Design and Construction Standards (CSDCS) while also considering to setback requirements from the Trackway. These LRT related setbacks are based on both operational and maintenance concerns.

- Deciduous trees: trunk must be planted a minimum of 2.5 m from edge of Trackway
- Coniferous trees: trunk must planted be a minimum of 4.0 m from edge of Trackway
- Shrubs: spread at maturity must be at least 0.5 m from edge of Trackway
- Ornamental and naturalized grasses may be planted up to the edge of the Trackway

In addition to these setbacks, further guidelines for landscape planting are described in the sections below.

14.4.2 Trees

City of Edmonton policy requires the planting of trees along all major Transportation Corridors. New LRT construction often requires the removal of mature trees magnifying the imperative of providing extensive new tree plantings. Despite this, the required space for the Trackway, Street infrastructure, operations and maintenance access, emergency vehicle access, and Signals infrastructure constrains the room for tree planting. The Designer must therefore look for and take advantage of every reasonable opportunity to include new tree planting along the LRT ROW.

14.4.2.1 Species Selection

The D&CS and CSDCS provide a list of approved tree species for use as street trees. Any trees selected for planting along the LRT ROW must be from this list. These approved trees are based on generally accepted criteria including:

- Hardiness
- Significant canopy
- High-carbon capture
- High branch clearance
- Deep root systems
- Absence of messy or potentially hazardous fruit, seed or flower droppings
- Low hazard potential
- Disease resistance
- Long life

Locating trees adjacent to the LRT ROW presents an additional set of considerations and restrictions, particularly for trees located within the Urban Interface zone. While it is a generally accepted principle that street trees should have extensive canopies to provide filtered shade, trees planted adjacent to the Trackway must have very limited canopy which must not extend over the Trackway due to conflicts with the Overhead Contact System (OCS). While columnar trees meet this condition, they generally also have low growing branches which can impede Train Operator (TO) sight lines. Trees adjacent to the Trackway must therefore have both high branch clearance and a limited canopy spread. Trees with heavy leaf drop should also be avoided as wet leaves on rails lead to a reduced friction between Light Rail Vehicle (LRV) wheels and the track.

Boulevard trees located along the LRT ROW are not subject to the same restrictions as those directly adjacent to the Trackway in terms of habit and leaf drop. Tree selection for boulevard areas can help provide visual buffering of LRVs, OCS infrastructure, signal infrastructure, and barriers or safety equipment and should therefore be selected based on these considerations where appropriate.

14.4.2.2 Planting Strategies

Transportation Corridors that include LRT infrastructure require a higher level of design than a typical Street without LRT infrastructure. Landscape design should consider the high concentration of Passengers on the LRT as opposed to motor vehicle users and design the corridor to be viewed from an LRV as well as from surrounding Streets and buildings. Tree planting plans should emphasize species diversity both to provide ecological resilience and to reflect the character of individual communities along LRT ROW. Due to the clear divisions of LRT lines by Stations, the Designer should consider locating varying tree species along each of these sections.

14.4.3 Shrubs

14.4.3.1 Species Selection

As with trees, shrubs are desirable wherever practicable along LRT ROW. Shrubs should be selected based on a similar set of criteria to standard Transportation Corridor plantings. These criteria include overall hardiness, low maintenance and a maximum growing height of no more than 1000 mm to avoid impeding TO sight lines.

14.4.3.2 Snow Storage

As the LRT ROW generally has very limited space for shrub plantings, shrub beds are often located in snow clearing zones. Shrubs located in the Urban Interface zone will potentially be covered with snow from clearing the Trackway as well as with snow plowed off adjacent Streets. While the additional snow from track clearing does not generally contain high concentrations of harmful chemicals such as road salts, large piles of snow can turn to ice in the spring potentially causing damage to many shrub species. Shrub selection for plantings within the Urban Interface zone should emphasize hardiness to extensive snow cover. Raised curbs or low planters should also be considered in Urban Interface zone and in Station amenity areas to mitigate the effects of snow storage while also discouraging pedestrian access.

14.4.3.3 Soft Barrier Shrub Planting

As provided in Section 14.2.1.2 shrubs may be used to delineate areas within the LRT ROW, including Station amenity zones, as a soft barrier or in combination with delineation fencing. Shrubs used in this manner to discourage pedestrian access or delineate and direct active mode paths of travel should be tightly planted with dense branching. Thorny shrubs can be planted to further discourage pedestrian access to the Trackway.

14.4.4 Grasses

Naturalization seeding may be an option where shrub planting is not practicable due to maintenance or other issues. Naturalization strategies should also be considered on any slopes or drainage swales.

Planting beds and naturalization areas should be used rather than mown lawn areas along the LRT ROW. Certain exceptions may exist, including median areas at intersections, areas allocated for street snow storage, and areas that require vehicular emergency access.

14.4.5 Maintenance

Landscape maintenance protocols for plantings in the LRT ROW must be considered when designing planting plans. Maintenance of landscaped medians adjacent to the Trackway can present operational and safety issues for maintenance personnel. The Designer should select low-maintenance plantings that require minimal pruning or other hands-on maintenance. Plantings must not be located on medians or within the Urban Interface zone adjacent to single lane traffic as maintenance of these plantings would require total roadway closures and associated traffic detours.

Raised curbs or planters must also be accessible to maintenance personnel and powered landscaping equipment. Therefore, raised curbs and planters should not be higher than 500 mm and should provide ramp access for personnel and equipment and sufficient non-planted space for the safe movement of personnel. Where hard barriers do not exist between landscaped areas and the LRT ROW, the Designer should consider including low walls to delineate the edge of the Trackway for the safety of maintenance personnel.

14.4.6 Soil Cells

The area adjacent to the LRT ROW will typically have limited space for landscape planting both in width and depth. Tree plantings in median areas or in Station amenity and plaza areas where stormwater, Traction Power (TP), or other underground utilities exist should be installed with soil cells to prevent damage to LRT utility ducts and promote tree health. Soil cell layouts should be designed together with drainage systems to ensure holistic management of stormwater runoff on the LRT ROW and Urban Interface areas.

14.4.7 Mulch

Planting bed mulch for Urban Interface areas must be selected to avoid migration onto the Trackway. Wood chip mulch is susceptible to wind borne migration and should not be installed in these areas. Medium to large sized wood bark mulch and medium to large rock mulch are resistant to migration and may be suitable for use in the Urban Interface zone.

14.5 ACOUSTIC AND VIBRATION CONTROL

Noise created by operation of the LRT is governed by the City of Edmonton Urban Traffic Noise Policy C506A (UTNP) [253]. A noise study must be undertaken in support of the design for new or upgraded LRT facilities and noise mitigation must be provided if modelled sound levels exceed thresholds defined in the UTNP.

Vibration caused by operation of the LRT will generally only impact sensitive receptors in close proximity to the Trackway. A vibration analysis and report must be undertaken to identify sensitive receptors that may require mitigation.

14.5.1 Operational Noise

In a Transportation Corridor, LRV operating sound and Station related sounds, even when the LRT is running at short headways, are generally not a significant component of a 24-hour sound profile when measured or modelled as per the UTNP. New or enhanced noise attenuation due to the addition of LRT is more likely to be required when adjacent roadway traffic volumes are high or when LRT construction moves motor vehicle traffic closer to residences or sensitive receptors.

Localized short-term sounds related to LRT operation, including wheel noise over switch components, rail corrugation or other acoustic roughness, wheel squealing around tight curves, Station announcements and Light Rail Vehicle (LRV) door chimes must be considered by the Designer even though they may not require mitigation under the UTNP.

14.5.2 Construction Noise and Vibration

Noise and vibration as a result of LRT construction are not modelled as part of the noise study but are governed by the Community Standards Bylaw 14600 [79].

14.5.3 Safety Equipment Exception

Sound that serves to enhance the safety and security of Patrons, pedestrians and motorists is not modelled in the noise study, and mitigation to address safety related noise, including bells at crossings, is not required under the UTNP. However, the Designer should consider opportunities to reduce the impact of safety related sound wherever practicable while still maintaining full functionality of the warning system.

14.6 SIGHT LINES

The installation of the LRT infrastructure includes the Trackway, overhead catenary wires and poles, Signal masts, At-Grade crossing control measures, fencing, Stations, and other Ancillary Facilities. To prevent these elements from forming visual barriers for pedestrians, cyclists, and motor vehicle drivers, the Designer must integrate these elements in a cohesive and consistent manner.

Sight lines must be carefully considered at areas of hazard. Pedestrians and Patrons must be provided with unobstructed views of the LRT ROW and adjacent Streets. Similarly, TOs and motor vehicle drivers approaching an intersection must have a clear line of sight to pedestrian crossings, queuing and approach areas, adjacent SUPs, and cycle tracks. The Designer must give careful consideration to the impact of OCS poles and Signal System infrastructure on curved sections of track where the alignment of multiple poles in the middle to far visual field can create a visual barrier between the TO and a pedestrian, cyclist or motor vehicle approaching the Trackway.

Refer to Chapter 6, Traction Power for guidelines on the design of the OCS and supporting infrastructure.

14.6.1 Visual Clutter

Through minimizing visual clutter around Stations, wayfinding and other landmarks will become more prominent and recognizable to Patrons approaching the Station from the street or from an LRV. Refer to Chapter 10, Stations and Ancillary Facilities for guidelines on signage, branding, and wayfinding.

CHAPTER 15

Safety and Security

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INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

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15 SAFETY & SECURITY

15.1 INTRODUCTION

This chapter presents the principles and guidelines for measures to enhance the safety and security of Passengers and Patrons as well as Edmonton Transit System (ETS) service and maintenance staff in:

- Stations
- Adjacent pedestrian and bicycle facilities
- Parking areas
- Patron drop-off areas
- Light Rail Transit (LRT) Right-of-Way (ROW)
- Light Rail Vehicles (LRV)
- Ancillary Facilities

Where applicable, requirements of the Alberta Building Code (ABC) [152] and the National Building Code (NBC) [2] must be applied. Other industry standards including but not limited to National Fire Protection Association (NFPA) 130 [262], American Public Transportation Association (APTA) Standards Infrastructure and Systems Security [263], the Design Guide for a Safer City [206], and NFPA 101 [10] should be used when building codes do not address specific Design elements.

15.1.1 Applicable Codes, Standards, Regulations, Design References

- Alberta Building Code (ABC) [152]
- National Building Code of Canada (NBC) [2]
- NFPA – 130: Standard for Fixed Guideway Transit and Passenger Rail Systems [262]
- American Public Transportation Association (APTA) Standards Infrastructure and Systems Security [263],
- Design Guide for a Safer City [206]
- Barrier-Free Design Guide [264]
- City of Edmonton Zoning Bylaw #12800 – Regulation 58 General Performance Standards for a Safe Physical Environment [265]
- City of Edmonton Design and Construction Standards [257]
- Crime Prevention Through Environmental Design (CPTED) [266]
- NFPA -101: Life Safety Code [267]

15.2 SAFETY AND SECURITY DESIGN PRINCIPLES AND GUIDELINES

15.2.1 Safer City Principles

The City of Edmonton Design Guide for a Safer City [206] provides guidance on measures to provide a safer urban environment. The guide provides broad principles which are supported by other measures, including awareness of the surrounding environment, visibility by others, and finding help.

15.2.2 General Guidelines for All Transit Facilities

The Design Guide for a Safer City [206] discusses safety and security concerns and presents specific guidelines for At-Grade and Grade Separated Stations, Ancillary Facilities, Park and Ride lots, sidewalks and Shared Use Paths (SUP), and pedways. The Guide provides information on:

- Sight lines
- Avoidance of entrapment spots
- Signs and information
- Reduction of isolation
- Transit shelter design
- Lighting
- Maintenance
- Formal surveillance

15.2.3 LRT Facility Interior and Exterior Access Routes and Areas

15.2.3.1 Sight Lines

Clear visibility of the path along a given travel route is critically important. A user's sight line should not be obstructed by any physical element including sharp corners, walls, earth berms, fences, landscaping, waste receptacles, signs, or columns. Where Grade Separated facilities and/or landscape screening are required for functional or aesthetic reasons, they must be assessed against the potential risk to personal safety and approved by the Engineer.

Sight lines should be unobstructed based on users that include pedestrians (adult or child and wheelchair height), cyclists, motor vehicle operators and Train Operators (TO).

15.2.3.2 Predictable Routes, Entrapment Areas, and Isolation Points

Predictable routes offer limited escape alternatives for users. An attacker can predict where pedestrians will be in pedestrian tunnels, overpasses, escalators, and staircases. Predictable routes are of particular concern when they are isolated or when they terminate in entrapment areas such as dead ends. Entrapment areas can be small, confined spaces near or adjacent to well-traveled routes that are shielded on three sides by barriers such as walls, fences or dense landscaping. Isolation points are areas that have limited activity such as parking lots and parkades.

The Designer should:

- Promote visibility by providing clear sight lines
- Introduce surveillance measures and indicators
- Consider introducing activity functions
- Provide appropriately placed emergency phones
- Provide appropriate security and emergency lighting
- Close or lock entrapment routes if they cannot be eliminated
- Place mirrors in areas with poor sight lines such as stairwells

Use mirrors to aid the TO with sight lines when entering Stations

15.3 LRT SYSTEM SAFETY AND SECURITY FEATURES

Specific Patron-orientated safety and security features that are required in the design of system elements and components are described below.

15.3.1 Surveillance

Designing open and obstacle-free areas will provide natural surveillance and reduce the opportunity for crimes against persons and property. Formal surveillance such as Closed-Circuit Television (CCTV) and signage indicating that an area is under surveillance can discourage unlawful activities. Providing emergency phones in accessible locations allows Patrons a greater sense of security while using the LRT System.

15.3.1.1 ETS Control Centre

The ETS/LRT Operations Control Centre (OCC) and the Security OCC play a vital role in providing a safe and secure experience for Patrons of the LRT System. Surveillance monitoring, intrusion detection and emergency response to both safety and security issues are initiated and monitored from these locations. To achieve the required level of safety and security, all safety and security devices that are installed on the LRT ROW, in Stations and Ancillary Facilities, and at bus stops, Park and Ride lots and public locations associated with the LRT System must have the appropriate infrastructure to support this objective. Refer to Chapter 8, Communications for additional information.

15.3.1.2 Closed Circuit Television

The LRT System is equipped with a CCTV surveillance system that assists in management of Train operations, public and ETS staff safety, and security. The system is comprised of video imaging, processing, display, and recording equipment along with its own dedicated video transmission system. Cameras are remotely controlled from the LRT OCC and the Security OCC.

The Designer must carefully consider the placement of cameras in public gathering spots when associated with the LRT System and Park and Ride locations.

The CCTV surveillance system serves both operational and security needs. Operational needs are those deemed necessary for the safe movement of Patrons, as well as aiding investigations to determine the cause of incidents. Security needs are those deemed necessary for the protection of assets, prevention of vandalism or intentional acts resulting in harm to Patrons and employees.

Camera coverage must be provided for the following security sensitive areas:

- Entrances to cash vaults
- Ticket distribution and payment equipment such as Smart Fare Vending Machines (SFVM) and validators
- Emergency telephones
- Elevator interiors, entrances, and exits
- Escalators
- Washroom entrance doors
- Kiosks
- At-Grade crossings
- Entrances to and exits from parking areas
- Park and Ride locations
- Service, security or operations room entrances
- All Platform areas
- Facility entrance doors
- Tunnel portals and bridges
- Ancillary Facilities
- Pedway, Walkway, and stairwell entrances, and exits
- Station access routes and adjacent parking areas
- Bicycle racks
- Loading areas

Camera locations must be designed to provide optimal coverage, avoid blind spots, and situate equipment at a height where opportunities for vandalism are minimized. Infrastructure should be provided on all lighting poles to allow for future camera installation.

Camera views of fare collection and fare paid areas will monitor free flowing operations and detect flow obstructions. Activity must be identifiable for a distance of at least 45 m from the camera location.

Alarms generated from emergency phones, emergency call stations, ticket vending machines, vaults, elevators, or washrooms must immediately trigger their respective camera views. The security OCC must be able to display and record a minimum of five emergencies or alarm situations simultaneously.

For technical information on cameras and supporting infrastructure, cabling and connectivity refer to Chapter 8, Communications.

15.3.1.3 Telephone Systems

General emergency, elevator emergency, and washroom access phone systems must be provided on the LRT System and be available for public use.

Emergency phones must be placed in locations that are easily accessed, visible, and identified for emergency use. Emergency phones must be readily identifiable using high visibility color, lettering or markings. A minimum of two emergency phones must be placed on all Platforms with direct connection to the security OCC and monitored by CCTV. Parking structures must have emergency phones at elevators and stairways at each level of the parking structure as well as any pedestrian access or egress locations from the structure. When an emergency phone is activated, the video monitoring system must generate an alarm and show a minimum of 15 seconds of video prior to the alarm. The video recording is to be accessible at the security OCC.

Emergency phones should also be placed in any public area associated with the LRT System that would be considered a predictable route, entrapment area, and or isolation point, including inside elevators. An emergency phone placement plan must be submitted with the Design for approval by the Engineer and the Operator.

LRT ROW telephone systems, identified with a blue light in tunnel sections, are to be provided on the LRT System specifically for ETS employee and Contractor use. LRT ROW phones must be placed near all Interlockings, At-Grade crossings, Cross-Connections, and each end of Platforms.

For technical information on telephone systems refer to Chapter 8, Communications.

15.3.1.4 Public Address and Variable Message Sign Systems

Voice paging announcements to Patrons are required for LRT security and operations messages.

All Stations on the LRT System must be equipped with amplified Public Address (PA) and Variable Message Sign (VMS) systems. Stations must have speakers at Platforms, on Concourses, and in pedway areas to provide information on safety and security issues as well as public service announcements such as train arrival information. PA loudspeakers must operate in a zoned manner to allow individual area announcements, Station specific announcements, and system wide announcements.

Refer to Chapter 8, Communications for guidelines and criteria to be used in the Design of PA/VMS systems.

15.3.2 Stations/Facilities

15.3.2.1 Public Restricted Zones

Public access to restricted and potentially unsafe areas within the LRT ROW, Stations, and Ancillary Facilities must be prevented through:

- Exclusion by way of hard barriers, locking gates, fences, or remote-controlled doors with status indicators
- Intrusion alarms, motion sensors, and detectors which trigger CCTV alarms
- Steep gradients to prevent climbing
- Soft barriers or delineation in the form of landscaped or other surface treatments
- An Owner approved door access system for Ancillary Facilities which generates a CCTV alarm when accessed
- Locking cabinets for signaling and communications equipment which generates a CCTV alarm when opened
- Signage indicating unsafe conditions (e.g. proximity to high voltage)

15.3.2.2 Patron Elevators

For security reasons, at least one transparent side must be provided in an elevator car at each stop position. Refer to Chapter 10, Stations and Ancillary Facilities for additional information.

All elevators must be equipped with a hands-free direct dial telephone that connects with the security OCC. The telephone must include braille directions plus a call connect indicator light. In parking structures, emergency phones must be located outside elevators on each level.

15.3.2.3 Public Washrooms

Public washrooms are to be provided with special access and security features. These include:

- Locking/unlocking of all doors controlled remotely by the security OCC
- A hands-free direct dial phone connected to ETS Security located on the exterior wall near the washroom doorway for access requests
- A power door opener to automatically open the washroom door once ETS Security has remotely activated the door release but which must not unlock the thumb latch used in single occupancy washrooms
- A doorway sensor to prevent closing on an occupant
- An exterior lit "Occupied" sign for single occupancy washrooms, located near the washroom doorway and activated by motion sensors inside the washroom which must be visible from to the security OCC via CCTV
- A thumb latch equipped with an “occupied/unoccupied” indicator to lock single occupancy washrooms from the inside
- An automatic door paddle located adjacent to the door inside the washroom allowing the door to open automatically when the paddle is pressed
- An interior hands-free direct dial emergency phone to the security OCC mounted on the wall of the washroom
- Emergency lighting for Patron safety during local power outages

Refer to Chapter 10, Stations and Ancillary Facilities for additional information.

15.3.2.4 Lighting
Lighting Design must provide the following:

- Adequate and uniform illumination levels in each area to avoid shadows created by weak or uneven coverage
- Nighttime light levels that are high enough to allow Patrons to recognize and identify objects and events without causing glare
- Illumination above each exterior door on Ancillary Facilities
- Emergency lighting for all Station areas and rooms regularly accessed by the public or ETS staff
- Battery powered emergency lighting in conformance with local building codes and applicable NFPA codes
- Avoidance of spotlighting points, which leave surrounding areas less visible
- Lighting devices that are easy to maintain, reliable, weather resistant, and vandal resistant

Refer to Chapter 10, Stations and Ancillary Facilities and Chapter 11, Electrical for more information.

15.3.2.5 Acoustics and Vibration
Unnecessary or conflicting noises create confusion and cause difficulties when Patrons are assessing safety and security issues, such as listening to the public address system or using help phones. Acceptable noise and vibration levels and acoustical characteristics aimed at reducing the echo effect should be considered.

15.3.2.6 Wayfinding
Well designed and appropriately located signs and maps contribute to a feeling of security. Signage must be strategically located and plainly visible from the reader's height, provide clear and understandable, messages, and be consistent. Refer to Chapter 10, Stations and Ancillary Facilities.

Tactile surfaces provide visually impaired Patrons with a detectible contrast to the surrounding floor. This type of warning surface must be placed on all Platform edges to warn patrons of their proximity to a hazard. Refer to Chapter 10, Stations and Ancillary Facilities for additional information.

15.3.2.7 Fare Equipment
Fare equipment must be continuously monitored by CCTV cameras and an alarm must be generated when the equipment is opened. Refer to Chapter 10, Stations and Ancillary Facilities for additional information.

15.3.3 Station Exterior Areas
Exterior areas of Stations, including sidewalks, pedways, parkades and surface parking lots, require special consideration for access through the strategic placement of entrances, exits, signage, lighting, landscaping, and fencing.

Sight lines and view obstructions must be considered during landscape design to avoid the creation of blind spots or entrapment areas as vegetation matures. Sudden changes in grade due to landscaping should be avoided as they may impede sight lines.

Parking structures must be designed to allow facilities to be securely locked down to motor vehicles and pedestrians to minimize the potential for vandalism and tampering with the structure's security system.

Emergency response parking must be provided at Station entrances, and Station elevators.

Grounded fencing must be provided for all surface LRT Park and Ride lots.

The following guidelines also apply:

- Sidewalks and pathways must provide direct Patron routing to each Station entrance
- Patron loading zones must be placed near the Station entrance, and should avoid routing vehicles through Park and Ride areas
- Conflict points between motor vehicle, pedestrian, and bicycle traffic must be avoided in parking lots, circulation areas, and access roadways
- Patron Drop-Off areas and short-term parking must be provided near to, and visible from, Platforms and/or Station entrances
- Dead-end drive aisles are not permitted
- Illumination levels must be in accordance with Chapter 11, Electrical
- Stairwells and connecting Walkways to parkades must have doors that can be locked to prevent access to the parkade but allow any Patrons remaining inside to exit

15.3.4 LRT Right-of-Way

15.3.4.1 Grade Separated Access

Design of Grade Separated LRT facilities must provide for safe evacuation of Passengers in the event of a Train breakdown or fire. Safe egress must be provided by designated egress Walkways.

Emergency lighting must be provided for Patron safety in enclosed tunnels exceeding 100 m in length from portal to portal, and in all tunnels where a portal is not visible.

Safe access along an At-Grade Trackway must be provided. An access zone a minimum of 600 mm wide must be provided on each side of the Trackway within the LRT ROW if hard barriers prevent movement away from the Trackway. Where necessary, both access zones and Refuge Zones may be replaced with a single access zone or Refuge Zone between each set of tracks in accordance with NFPA 130 [262]

Tunnel sections must have yellow advisory lights at each tunnel entrance with unobstructed sight lines for the TO.

Tunnel Cross-Connections must be provided at a maximum spacing of 500 m.

15.3.4.2 Bridge or Elevated Trackway Access

Design of bridges and elevated Trackways must allow the safe evacuation of Passengers in the event of a Train breakdown or fire. Safe egress may require the provision of Designated Egress Walkways and Refuge Zones if hard barriers prevent movement away from the Trackway.

Adequate lighting must be provided for emergency evacuation along a designated egress Walkway.

Safe access along a Grade Separated Trackway must be provided. Designated egress Walkways and Refuge Zones must be provided on each side of the elevated Trackway or bridge within the LRT ROW.

15.3.4.3 At-Grade Track Crossings

Infrastructure requirements for actively controlled crossing of the LRT ROW are provided in Chapter 7, Signals. Safety measures at motor vehicle, cyclist, and pedestrian At-Grade crossings are provided in Chapter 17, Streets.

15.3.4.4 LRT Right-of-Way Hazards

Tripping hazards such as Speed Checks, impedance bonds, vault openings and surface-run conduit should be identified in yellow to caution ETS staff and contractors working on the trackway. Any surface conduit which does not run between the rails should be considered for a cable ramping system to protect the cable and improve safety for workers.

Pinch points and areas of limited clearance that could impact worker safety must be clearly identified.

Radio communication systems must be designed such that handheld and LRV radio equipment provides greater than 99% reliable communication within 95% of the LRT ROW. Refer to Chapter 8, Communications.

Sight lines for Train Operators of LRVs and rail borne maintenance vehicles should be considered when placing LRT ROW elements such as bungalows, cabinets, and crossing controls. Sight lines for motorists, cyclists and pedestrians using At-Grade crossings should also be considered when placing infrastructure on the LRT ROW.

15.3.4.5 Fire-Life Safety System

The Design of a smoke removal system for underground facilities, if required, will require extensive coordination with the Operator and with Edmonton Fire Rescue Services (FRS) and must meet the minimum requirements of the ABC [152] and NFPA 130 [262].

All tunnel sections of the LRT ROW must consider the need for fire-life safety systems. Each tunnel section must have a hazard assessment completed to determine if fire-life safety systems are required.

15.3.4.6 At-Grade Crossing Controls

The required controls for At-Grade crossings of the LRT ROW are dependent on the type of operation as provided in Chapter 1, General, Chapter 7, Signals and Chapter 17, Streets.

15.3.5 Light Rail Vehicles

Safety and security features to be incorporated in LRVs include:

- A two-way radio system housed in the LRV cab used by the TO in communicating with the LRT OCC, other Trains, and maintenance or supervisory staff
- A magnetic Train control system that safeguards Train movements by automatic initiation of braking action should a Train overrun or pass a Signal conveying a restrictive aspect or pass through a Speed Check at a rate that exceeds the allowable speed. Refer to Chapter 7, Signals

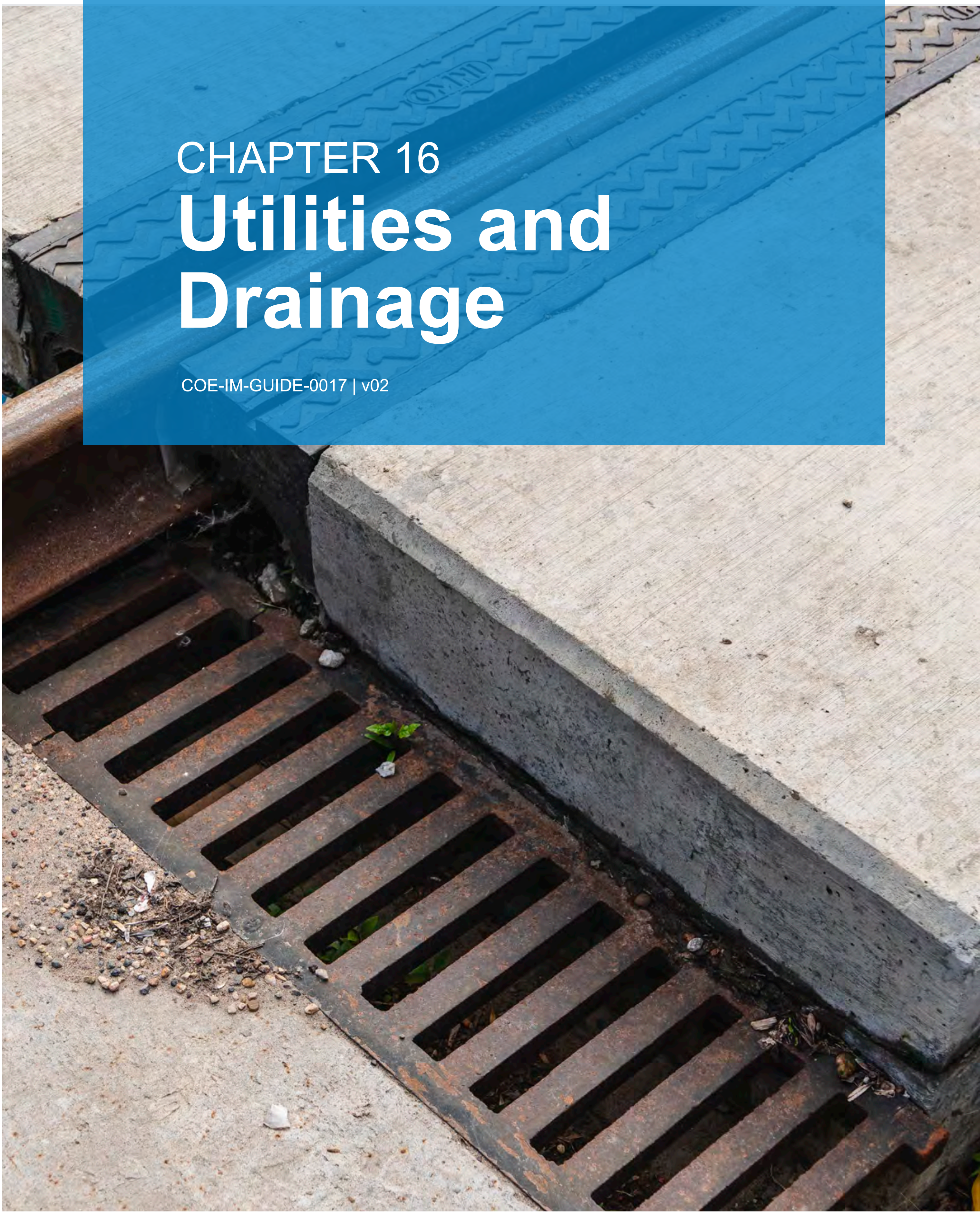
15.3.6 Ownership, Maintenance, and Management

LRT property must be maintained to create a secure environment. Public assets require consistent maintenance and management, and that maintenance, whether for a Station, the LRT ROW, or an LRV, is paramount. Assets should be designed to be easily maintained with minimal disruption to service delivery. The Designer should discourage vandalism through properly designed lighting and CCTV camera placement and the use of vandalism-resistant materials for emergency LRT ROW phones and Station furniture. The Designer should also use waste receptacles that are highly visible and placed to minimize litter, and that are constructed such that projectiles are not created if an explosive device is placed inside the receptacle. The receptacles should also be designed to allow the contents to be viewed from a distance.

Winter maintenance is a key operational requirement. Snow storage areas must be included in the design of all Stations and Ancillary Facilities such that snow piles do not interfere with the movement and safety of Patrons. Snow storage locations must not create entrapment areas or cause obstructed sight lines.

15.3.7 Protection of Tunnels Entrances or Portals

All portals where LRVs move from open air sections to tunnels must be designed to minimize opportunities for non-authorized access. This includes portal with nearby public area, such as sidewalks, plazas or parks adjacent to the portal, as well as areas that would require a person to trespass to gain entrance to the area. The design of the portal must prevent a person from entering the track area from the sides or top of the portal. This protection must also prevent a person standing on the ground from throwing projectiles or debris onto or at LRVs from above. The Designer must consider the interaction of any protective measures with the OCS system.



CHAPTER 16

Utilities and Drainage

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INTENT OF USE

This guideline, including all its appendices, was developed to establish the City of Edmonton expectations for the design and construction of their High Floor LRT infrastructure assets. The views expressed herein do not necessarily represent those of any individual contributor, and may reflect current and/or historical design practices unique to the Edmonton LRT system. As design practices change and evolve over time, readers must consult current technical standards, codes, and other publications rather than relying on this publication exclusively. The City of Edmonton, the authors, and members of the document review committee express that this document does not constitute any part of a project specific design. As such, no part of this document alleviates the responsibility of the professionals retained to design and/or construct specific LRT projects from taking full responsibility for and for authenticating their designs in accordance with APEGA, AALA, AAA, the Alberta Building Code, and any other statutory or safety requirements.

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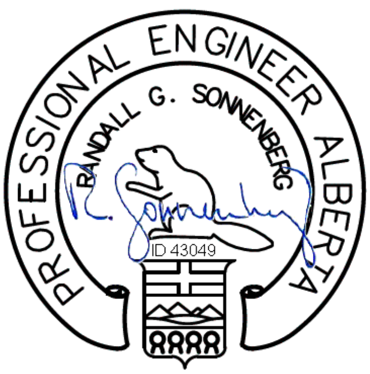

29-Mar-2022

Permit to Practice

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16 UTILITES & DRAINAGE

16.1 INTRODUCTION

Design guidelines for the following utility related elements are included in this chapter:

- The relocation, adjustment, or abandonment of existing utilities within the existing or proposed Light Rail Transit (LRT) Right-of-Way (ROW), Urban Interface zone, and the adjacent Streets
- The placement of new utilities across the LRT ROW
- The placement of new utilities parallel to the LRT ROW
- The placement of utility services that are required for the operation of any new or upgraded LRT facilities
- The design of minor and major stormwater management systems within the LRT ROW and the interaction with adjacent drainage areas

16.1.1 Applicable Codes, Standards, Practices, and Reference Guidelines

All utility work must be designed in accordance with the applicable standards and criteria established by the utility owner/service provider and the standards and criteria of the local jurisdictional authorities, as appropriate.

The Utility Line Assignment (ULA) permitting process, per City of Edmonton Bylaw 12846 [268], is the regulation of work and equipment installation on City lands. The Designer must be mindful of the ULA process and the accompanying regulations.

The City of Edmonton Design and Construction Standards manual (D&CS) [269] governs the design of utility infrastructure that is to be operated and maintained by the City. The Designer must refer to this document for Design related criteria for storm and sanitary sewers, water infrastructure, and shallow utilities. The Designer must also refer to the latest version of the EPCOR IDF Curves [270], as the design storm information included in this document takes precedence over information in the D&CS.

16.2 UTILITY RELOCATION, ABANDONMENT, AND MITIGATION

16.2.1 General Design Guidelines

Underground utilities parallel to the Trackway are generally not permitted in the LRT ROW but may be permitted within the Urban Interface zone depending on the type of utility and if adequate width exists between the utility and proposed LRT barriers or fences. Refer to Section 16.3 for details on utilities permitted within the Urban Interface zone.

Cellular towers should be located outside of the Transportation Corridor and must be evaluated on a case-by-case basis.

Appurtenances including but not limited to manholes, valves, vaults, cabinets and cubicles, must not be located in the LRT ROW.

Utilities must cross beneath the LRT ROW at a 90º angle to the LRT track centreline.

Utilities within the Transportation Corridor, with less than the required parallel and crossing parameters defined below and in Appendix 16A must be sleeved or cased and approved by the Engineer and the utility provider. Casing should be non-conductive, continuous, and extend a minimum of 6.0 m beyond the track centreline on both sides of the LRT ROW. If non-conductive casing is not practicable, appropriate corrosion protection must be provided. Refer to Chapter 13, Corrosion and Stray Current for additional details.

All utilities beneath the LRT ROW that are to be abandoned must be removed. If removal is not practicable, then they may be abandoned in place as accepted by the Engineer.

Utility crossings that are added following LRT construction may be installed using trenchless methods with the acceptance of the Engineer. However, the Designer must consider the provision of ducts, conduits, or casing for future utility installations if the future utility crossing sizes and locations have been defined.

Utilities must be designed and constructed to minimize the impact of Stray Current. Where practicable, utilities should be constructed with non-conductive material. Refer to Chapter 13, Corrosion and Stray Current for additional information.

Existing utilities impacted by LRT construction must be:

- Maintained in place and in operation during construction if they do not present an impediment to LRT construction as scheduled
- Temporarily relocated and maintained in operation during construction
- Temporarily relocated and maintained, then, upon the completion of LRT construction, replaced by a new utility installation
- Permanently relocated to a new location in accordance with LRT utility separation requirements

Any utility servicing private property within the Transportation Corridor must not be interrupted by construction of the LRT. If temporary service to private properties must be provided it should be installed to be permanent at the completion of LRT construction.

New installation of any existing utilities should be designed to provide service equal to that provided by the existing installation. No betterment of service is to be provided unless specifically directed by the Engineer.

Where the LRT ROW crosses buried or aerial power transmission lines, gas, oil, or other high-pressure pipelines, a crossing agreement with the utility service provider must be obtained. Further details on this requirement are provided in Volume 1 of the D&CS.

16.3 INSTALLATION

16.3.1 General Design Guidelines

16.3.1.1 All LRT Utilities

All utilities designed to support LRT implementation must conform to the applicable codes, standards regulations, and requirements of the utility service provider and the City of Edmonton, as the Authority Having Jurisdiction (AHJ).

Other chapters in these guidelines provide direction on specific utility requirements for LRT infrastructure and Ancillary Facilities.

16.3.1.2 LRT Utility Placement for At-Grade Trackway

For clearance requirements and typical placement of major LRT utilities for surface and open portal sections including LRT duct banks, Signal cabinets, Signal devices and vaults refer to Chapter 6, Traction Power, and Chapter 8, Communications.

Utilities not associated with the LRT must follow the separation and crossing requirements for each utility type as described in the following sections and as summarized in Appendix 16A, Utility Placement Parallel to and Crossing the LRT ROW.

16.3.1.3 LRT Utility Placement in Tunnels

For clearance requirements and typical placement of major LRT utilities for tunneled sections, including LRT duct banks, signal cabinets, signal devices and vaults refer to Chapter 6, Traction Power, and Chapter 8, Communications.

Ducts, conduits and pipes must cross the Trackway at right angles.

The vertical clearance from the bottom of any duct, conduit, or pipe crossing the Trackway to the Overhead Contact System (OCS) contact wire must be a minimum of 500 mm.

16.3.2 Storm, Sanitary, and Combined Sewers

16.3.2.1 Parallel to LRT Right-of-Way

Existing sewer infrastructure located 2.0 m or less from edge of LRT ROW to edge of pipe for pipes with 7.0 m or less cover (from existing ground to pipe obvert) must be relocated. New or relocated sewer infrastructure must be a minimum of 2.0 m from edge of LRT ROW to edge of pipe. Existing sewer infrastructure within or adjacent to the LRT ROW with greater than 7.0 m of cover does not require relocation subject to a pipe condition assessment and acceptance by the Engineer and utility provider. Existing sewer infrastructure located 3.0 m or less from the outside of proposed tunnel or trench walls to the edge of pipe must be relocated. New or relocated sewer infrastructure must be a minimum of 3.0 m from outside of tunnel/trench walls to edge of pipe.

Manholes, catch basins, and other sewer appurtenances must meet the minimum clearance requirements described above, including manholes for sewers with greater than 7.0 m of cover.

Sewers may be located within the Urban Interface zone if adequate width exists and upon approval of the Engineer on a case-by-case basis.

16.3.2.2 Crossing LRT Right-of-Way

Minimum cover of 2.0 m from Top of Rail (TOR) to pipe obvert is required for sewer pipes crossing the LRT ROW, including sewer services. Sewers and sewer services crossing the LRT ROW must be protected from freezing as per the D&CS. Casing is not required for gravity sewers crossing the LRT ROW that meet the minimum cover requirements. Sewer pipes crossing the LRT ROW must be cased for a minimum of 6.0 m beyond the track centreline on both sides of the LRT ROW unless they have more than 7.0 m of cover or are greater than 750 mm in diameter. Pressurized sewer pipes must always be cased regardless of their depth or diameter.

16.3.2.3 Within LRT Right-of-Way

Manholes, catch basins, and other sewer appurtenances whose primary function is not drainage of the LRT ROW must be relocated out of the LRT ROW and meet minimum clearance requirements described above.

Sewers, services and catch basin leads should avoid crossing Platforms. Sewer infrastructure crossing a Platform must be cased and pipe location and depths must avoid conflicts with the Platform foundation.

16.3.3 Water Infrastructure

16.3.3.1 Parallel to LRT Right-of-Way

Existing water infrastructure located 2.0 m or less from edge of LRT ROW to edge of pipe must be relocated. New or relocated water infrastructure must be a minimum of 2.0 m from edge of LRT ROW to edge of pipe.

Existing water infrastructure located 3.0 m or less from the outside of proposed tunnel/trench walls to the edge of pipe must be relocated. New or relocated water infrastructure must be a minimum of 3.0 m from outside of tunnel/trench walls to edge of pipe.

Valves and other water appurtenances must be relocated to meet minimum clearance requirements. Thrust blocks around water appurtenances that extend hydrants into the clearance zone must be approved by the Engineer but must not encroach into the Trackway.

Water infrastructure may be located within the Urban Interface zone if sufficient width exists and upon approval of the Engineer on a case-by-case basis.

16.3.3.2 Crossing LRT Right-of-Way

Minimum cover of 2.0 m from top of rail to pipe obvert is required for water infrastructure, including water services, crossing the LRT ROW.

Water infrastructure crossing the LRT ROW must be protected from freezing as per the D&CS.

Pressurized water lines and services crossing the LRT ROW must be cased for a minimum of 6.0 m beyond the track centreline on both sides of the LRT ROW.

16.3.3.3 Within LRT Right-of-Way

Hydrants, valves, and other water appurtenances must be relocated out of the LRT ROW to meet minimum clearance requirements. Thrust blocks around water appurtenances that extend into the clearance zone must be approved by the Engineer but must not encroach into the Trackway.

Water infrastructure, including water services, should avoid crossing Platforms. Water infrastructure crossing a Platform must be cased and pipe location and depths must avoid conflicts with the Platform foundation.

16.3.3.4 Fire Protection

The provision of fire hydrants specifically for emergency response to the LRT ROW is not required. However, if fire hydrants are required in the Transportation Corridor to provide fire protection for structures adjacent to the LRT ROW, they must be located on both sides of the LRT ROW.

16.3.4 Shallow Utilities

16.3.4.1 Parallel to LRT Right-of-Way

Requirements for the various types of shallow utilities parallel to the LRT ROW are as follows:

Natural Gas

Existing gas infrastructure located 1.0 m or less from edge of LRT ROW to centreline of pipe must be relocated. New or relocated gas infrastructure must be a minimum of 1.5 m from edge of LRT ROW to centreline of pipe.

Appurtenances must be relocated to meet minimum clearance requirements.

Natural gas infrastructure may be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a case-by-case basis.

Distribution Power – Primary and Secondary

Existing power infrastructure located 1.0 m or less from edge of LRT ROW to centreline of utility must be relocated. New or relocated power infrastructure must be a minimum of 1.5 m from edge of LRT ROW to centreline of utility.

Transformers, switching cubicles, and any other above-grade infrastructure must be relocated to meet minimum clearance requirements, including ground rod locations.

Vaults and any other below-grade infrastructure must be relocated to meet minimum clearance requirements.

Power easements must not extend into the LRT ROW.

Power distribution infrastructure may be located within the Urban Interface zone if sufficient width exists and upon approval of the Engineer on a case-by-case basis.

Transmission Power

Buried power transmission infrastructure parallel to the LRT ROW must be evaluated for relocation through discussions with the utility provider and the Engineer on a case-by-case basis.

Telecommunications

Existing telecommunications infrastructure located 1.0 m or less from edge of LRT ROW to centreline of utility must be relocated. New or relocated telecommunications infrastructure must be a minimum of 1.0 m from edge of LRT ROW to centreline of utility.

Telecommunications pedestals and any other above-grade infrastructure must be relocated to meet minimum clearance requirements, including ground rod locations.

Vaults and any other below-grade infrastructure must be relocated to meet minimum clearance requirements.

16.3.4.2 Crossing LRT Right-of-Way

Requirements for the various types of shallow utilities parallel to the LRT ROW are as follows:

Natural Gas

Minimum depth of installation of 1.83 m from TOR to pipe obvert is required for gas infrastructure crossing the LRT ROW.

Casing of gas infrastructure is not required, but if casing is used it must be non-conductive, continuous, and extend a minimum of 6.0 m beyond track centreline on both sides of the LRT ROW.

Distribution Power – Primary and Secondary

Minimum depth of installation of 1.83 m from TOR is required for power distribution infrastructure crossing the LRT ROW.

Power distribution infrastructure crossing the LRT ROW must be in conduit. Conduit must be non-conductive, continuous, and extend a minimum of 6.0 m beyond the track centreline on both sides of the LRT ROW.

Transmission Power

Buried power transmission infrastructure crossing the LRT ROW must be evaluated for relocation or protection through discussions with the utility provider and the Engineer on a case-by-case basis.

Telecommunications

Minimum depth of installation of 1.83 m from TOR is required for telecommunications infrastructure crossing the LRT ROW.

Telecommunications infrastructure crossing the LRT ROW must be in conduit. Conduit must be non-conductive, continuous, and extend a minimum of 6.0 m beyond the track centreline on both sides of the LRT ROW.

16.3.4.3 Within LRT Right-of-Way

Shallow utilities that do not service the LRT are not permitted within the LRT ROW.

Exposed natural gas lines servicing Stations must only enter the Station from an end wall. This requirement is to reduce the risk of the gas line being contacted by Operations and Maintenance (O&M) personnel.

16.3.5 Pipelines

16.3.5.1 Parallel to LRT Right-of-Way

Required separation between parallel pipeline rights-of-way and the LRT ROW must be assessed to ensure that adequate space is provided for pipeline and LRT O&M activities. Coordination between the pipeline owner and the Engineer will define clearance requirements.

16.3.5.2 Crossing LRT Right-of-Way

Pipelines carrying water, oil, gas, flammable, volatile, or other pressurized substances are to be suitably cased, or bridged with a structural concrete slab. Casing material must be designed to withstand LRT loadings. Steel casing, if used, must employ corrosion protection. Coordination between the pipeline owner and the Engineer will define crossing requirements.

The Designer must consider the protection of utilities and crossing of high-pressure pipelines during the design process. Refer to Volume 1 of the D&CS [269] as follows:

- Procedures for Crossing High Pressure Pipelines – Section 01561
- Procedures for Protection of Existing Utilities and Structures – Section 01562

16.3.5.3 Within LRT Right-of-Way
Pipeline infrastructure is not permitted within the LRT ROW or Urban Interface zone.

16.3.6 Overhead Utilities

16.3.6.1 Adjacent to LRT Right-of-Way
Overhead power distribution or telecommunications poles must be located a minimum of 9.0 m from centreline of track and outside of the Urban Interface zone.

Proximity of the LRT ROW to overhead power transmission lines must be assessed on a case-by-case basis in discussion with the utility provider and the Engineer.

16.3.6.2 Crossing LRT Right-of-Way
Overhead power distribution or telecommunications poles must be assessed for vertical clearance and potential relocation or raising on a case-by-case basis in discussion with the utility provider and the Engineer.

Overhead power transmission lines crossing the LRT ROW must be assessed on a case-by-case basis in discussion with the utility provider and the Engineer. Precise location of towers and conductors must be determined by the Designer as part of the assessment.

16.3.6.3 Within LRT Right-of-Way
Overhead utilities not associated with the LRT must not be located within the LRT ROW.

16.3.7 Cellular Towers

16.3.7.1 Adjacent to LRT Right-of-Way
Cellular towers should be located outside of the Transportation Corridor and must be assessed on a case-by-case basis in discussion with the telecommunications provider and the Engineer.

16.4 STORMWATER MANAGEMENT DESIGN

LRT stormwater management is not only required for the collection of stormwater and prevention of flooding on the Trackway, but also to prevent flooding and negative impacts to the non-LRT areas adjacent to the Trackway due to the implementation of LRT infrastructure.

The LRT components that require drainage Designs are as follows:

- At-Grade LRT ROW
- Underground structures (tunnels, Stations, crossover cavities)
- Ancillary Facilities
- LRT overpasses, underpasses, and bridges
- Roadways, parking lots, sidewalks, Walkways and multi-use trails within shared LRT ROWs
- LRT related landscape areas
- LRT Stations (At-Grade or Grade Separated)
- Duct banks and vaults

Runoff from LRT elements that are directly exposed to rainfall is classified as storm drainage and is typically discharged into the storm sewer system. Sub-surface drainage on open track sections and underpasses is also classified as storm drainage. Storm drainage includes, but is not limited to, runoff from open ditches, roofs, roadways, parking lots, underpasses, aerial structures, retaining walls, and abutments. Stormwater management includes both quantity and quality management.

Runoff from LRT elements that are not exposed to rainfall is classified as sanitary drainage and is typically discharged into the sanitary sewer system. Sanitary drainage includes, but is not limited to, building structure plumbing, floor drains and drainage from underground tunnels/Stations. Sanitary drainage must not be permitted to enter the track drainage system.

16.4.1 Design Criteria

All LRT drainage Designs are to comply with the existing municipal standards (currently City of Edmonton D&CS [269] Chapter 3 Drainage, EPCOR's Guideline for Stormwater Management, Alberta Safety Codes Act [4], and Alberta Building Code Regulation [152]) and the additional LRT drainage criteria described below and in the following sections.

The stormwater management system must be sustainable, maximize the use of existing infrastructure, and protect downstream stormwater management systems and the environment.

Positive drainage away from all foundations must be provided.

Backflow prevention devices and any other suitable measures to protect the infrastructure from water intrusion must be installed on the stormwater management system when discharging to the combined sewer system. Discharge locations may include Trackway drainage systems, Trackway foundation drainage systems, stormwater storage elements, and stormwater Low Impact Development (LID) measures.

Heat tracing is to be provided for the following elements when exposed to freezing temperatures:

- Drainage troughs at portal entrances
- Drainage catchment areas at pedestrian ramps and stairs
- Sanitary drain lines
- Storm drain lines
- Roof drains

Refer to Chapter 11, Electrical and Chapter 12, Mechanical for more information on heat tracing.

16.4.1.1 Design Storm Events

All Trackway runoff collection infrastructure, including but not limited to pipes, culverts, ditches, storage, should be designed to accommodate the runoff flow rates and volumes as listed in Table 16.1.

The performance of the Trackway stormwater infrastructure must be analyzed through the following process:

- A review of the drainage characteristics adjacent to the Transportation Corridor on an area-by-area basis
- Development of adequately sized drainage facility scenarios for the 10, 25, 50, and 100 year storm events. The evaluation of the scenarios must include a feasibility analysis and cost implications of providing adequate drainage facilities at each storm level
- The presentation of a recommended scenario for implementation to the Engineer

Guidance must be sought from EPCOR Drainage to confirm:

- Historical storm intensities and related precipitation data for the area
- Capacity of the existing storm drainage system to accommodate the runoff from the proposed LRT ROW
- The possibility of the existing storm drainage system surcharging and flooding the proposed LRT ROW, facility or installation

Table 16.1 Storm Infrastructure and Design Storm Frequency

Storm Infrastructure	Design Storm Frequency
Tie and Ballast Track (subdrains or ditches)	1:25-year rainfall event
Embedded Track (storm conveyance pipes)	1:5-year rainfall event
Direct Fixation Track (storm conveyance pipes)	1:5-year rainfall event
Underpass Stormwater Management	Larger of the 1:100-year 4-hour and 24-hour rainfall event evaluated through discussions with the Engineer
Bridge Stormwater Management	Larger of the 1:100-year 4-hour and 24-hour rainfall event evaluated through discussions with the Engineer

16.4.1.2 Water Quality

The stormwater management system must not adversely impact runoff quality or increase the risk of spilled materials discharging to stormwater systems or receiving water bodies. Discharge from the stormwater management system must not contain substances that are environmentally damaging.

Discharge from the stormwater management system to the existing drainage stormwater management system must comply with the water quality requirements set out in Section 6.0 of the Municipal Policies and Procedures Manual, Alberta Environment: “stormwater management techniques to effect a minimum of 85% removal of sediments of particle size 75 µm or greater” (April 2001).

The Designer must provide accessible flow monitoring points upstream and downstream of all water quality treatment facilities, except catch basins and peak flow reduction facilities.

The Designer must provide trash guard systems to intercept trash and other materials that are likely to reduce the conveyance capacity of any existing stormwater management system.

The Designer must provide grit management measures to capture and prevent grit from being transferred to the existing stormwater management system or the environment. Grit management measures are to be sized to capture all grit from events up to and including the 1:2-year design event. The Design must provide appropriate access to all grit management measures for maintenance.

Grit management measures must be designed to prevent trapped materials from being flushed for all events up to and including the 1:100-year design event.

Water quality treatment measures, other than grit control (e.g. spill containment), must be provided where runoff water quality may be degraded, such as at Operations and Maintenance Facilities (OMFs) and bridges.

16.4.2 Minor Drainage

The minor drainage system for LRT stormwater management must provide positive drainage and seamless connectivity to existing minor drainage systems.

16.4.2.1 Peak Flow Mitigation

Peak runoff discharges from the Transportation Corridor (extent of change) to the existing minor drainage system during the 1:5-year design event must not exceed the 1:5-year pre-development flow rates, unless direction is given by the Engineer to increase or decrease the discharge flows based on existing capacity.

Peak runoff discharges from the Transportation Corridor (extent of change) to the existing minor drainage system during the 1:100-year design event must not exceed the 1:5-year pre-development flow rates, unless direction is given by the Engineer to increase or decrease the discharge flows based on existing capacity.

16.4.2.2 Peak Flow Reduction Measures

If LID measures are used as peak flow reduction measures, they must be designed according to the City of Edmonton Low Impact Development Best Management Practices Design Guide [271] and sized to meet the peak flow criteria in Section 16.4.3.1.

If structural soil cells are used as peak flow reduction measures, they must:

- Comply with the specifications provided by the manufacturer of the selected product
- Use a soil mix engineered to provide a minimum of 0.4 void ratio for water movement and water retention
- Incorporate trees and other plantings
- Incorporate catch basins to collect grit and convey local surface runoff into the structural soil cells for events up to and including the 1:5-year design event, spaced at a maximum of 50 m intervals
- Incorporate catch basins to distribute flows to the structural soil cells in a uniform manner and with a balanced distribution
- Incorporate means of preventing movement of fine materials into the minor drainage system.
- Provide positive drainage through the structural soil cells
- Discharge to the minor drainage system at maximum intervals of 200 m
- Incorporate a distribution and underdrain system that contains direct access from the surface and is a minimum of 200 mm diameter pipe with minimum diameter bends to accommodate inspection and flushing
- Incorporate catch basins that route surface runoff directly into the minor drainage system for events in excess of the structural soil cell capacity up to and including the 1:5-year design event and for periods when the structural soil cells are frozen

Utility infrastructure may be located through or longitudinally within the structural soil cells upon agreement with the applicable utility service provider.

16.4.3 Major Drainage

The major drainage system for LRT ROW stormwater management must provide positive drainage and seamless connectivity to the existing major drainage system.

The major drainage system must be a surface grading configuration that contains all surface runoff during events up to and including the 1:100-year design event within the Transportation Corridor, or storage facilities with surface inlets and leads capable of conveying surface runoff from contributing areas from events up to and including the 1:100-year design event into the storage facilities.

The major drainage system must include measures to prevent erosion or undermining of infrastructure.

16.4.3.1 Flood Mitigation of Trackway

Low lying areas of the Transportation Corridor must have sufficient stormwater drainage capacity to allow the LRT to continue to operate during periods of heavy rainfall. If practicable, retention ditches or ponds should be provided.

Ponding and overland flow within the Trackway must not exceed the TOR, other than embedded track, for events up to and including the 1:100-year design event.

Ponding and overland flow within the Trackway must not exceed the TOR for embedded track for events up to and including the 1:5-year design event.

Ponding and overland flow within the Trackway of embedded track for a design event in excess of the 1:5-year design event up to and including the 1:100-year design event must not exceed 100 mm or the maximum depth of water through which the Light Rail Vehicle (LRV) can pass without damage or disruption to operations.

Ponding and overland flow is not permitted at any point of safety, emergency egress pathway, crosswalk or in refuge areas within the Trackway for events up to and including the 1:100-year design event.

The Designer must be aware of the possibility that sections of direct fixation track that have a Trackway base at a lower elevation than the surrounding ground area may cause water to be impounded. Sunken direct fixation sections of track will require a drainage overflow point, storage or conveyance systems to maintain a water level below the TOR for events up to and including the 1:100 year-design event.

Table 16.2 on the following page provides a summary of the ponding and overland flow limits on the various types of Trackways.

16.4.3.2 Overland Flow

The Design of new LRT facilities and infrastructure must not adversely affect existing drainage courses.

The stormwater management system must not alter or disrupt existing overland flow patterns from areas external to the LRT ROW that flow onto, across, and off areas in the LRT ROW for embedded and direct fixation track types. Overland flow is permitted to cross, but not be conveyed along, direct fixation or embedded track.

Wherever existing overland flow patterns from areas external to the LRT ROW are altered or disrupted, such flow volumes must be controlled by the stormwater management system for events up to and including the 1:100-year design event.

Existing overland flow patterns from areas external to the LRT ROW that flow across areas of the LRT ROW that will be tie and ballast track must be prevented from entering the tie and ballast track sections by being intercepted, controlled and redirected away from the tie and ballast track sections by the stormwater management system for events up to and including the 1:100-year design event. Overland flow is not permitted to cross tie and ballast track.

Overland flow is not permitted to enter and then flow along the Trackway for any track type.

Table 16.2 on the following page provides a summary of the ponding and overland flow limits on the various track types.

16.4.3.3 Flood Mitigation of Adjacent Areas

Drainage from the LRT ROW must not adversely impact adjacent properties or the surrounding environment.

The stormwater management system must not increase surface ponding depths or create additional risk of flooding on adjacent properties.

The stormwater management system must contain runoff within the adjacent Streets and must not increase any currently occurring discharge to any adjacent properties for events up to and including the 1:100-year design event.

Table 16.2 Ponding Limits on Trackways

Track Type	1:5-Year Design Event Ponding Limit above Top of Rail	1:100-Year Design Event Ponding Limit above Top of Rail	Comments on Ponding/Overland Flow
Tie and Ballast Track	0 mm	0 mm	Ballast/sub-ballast must be free draining. Overland flow is not permitted to cross; stormwater to be controlled to the 1:100-year design event.
Embedded Track	0 mm	Lesser of 100 mm or safe LRV operation limit	Overland flow is permitted to cross.
Direct Fixation Track	0 mm	0 mm	Overland flow is permitted to cross. Impounded stormwater will require an overflow point, storage or conveyance system to maintain a water level below the top of rail for events up to and including the 1:100-year design event.

16.4.4 Trackway Drainage

The stormwater management system must include minor drainage and major drainage systems as required to comply with the guidelines in the previous parts of Section 16.4. The Design must provide positive drainage to all drainage inlets. The Designer must ensure that the tolerances specified for the concrete surface are achievable such that ponding of surface water will not occur. All track sections must be adequately drained to strategic collection points with gravity flow connections to sewers. Positive drainage away from the Trackway is required, except for locations where overland flow is designed to cross the Trackway.

Surface drainage from the Transportation Corridor must not drain onto private or City owned property adjacent to the corridor.

Surface velocity of stormwater runoff must not exceed 3 m/s for events up to and including the 1:100-year design event.

Trackway stormwater storage facilities may be located below the Trackway.

Cleanouts are required for all perforated drainage pipes at a maximum spacing of 140 m.

Trackway drainage Design must be undertaken in collaboration with the Design of the Trackway and adjacent roadways and bicycle/pedestrian facilities, as these elements are fully interdependent.

16.4.4.1 Tie and Ballast Track Drainage

Drainage systems for tie and ballast track may consist of drainage ditches or sub-drains depending on site constraints.

Drainage Ditches

Drainage ditches are permitted if there is sufficient space available along the LRT ROW. A site reconnaissance along the proposed LRT ROW should be carried out to determine if adequate drainage capacity can be created through proper drainage grades, outlets or retention areas.

Drainage ditches are to be sized to contain the 1:25 year-design event. The bottom of the drainage ditch must be a minimum of 500 mm below the shoulder of the LRT subgrade.

Baffles or riffle dams may be required to prevent scouring and deterioration of the subgrade for steep ditches with high flow velocities.

Sub-Drain System

A sub-drain system must be provided where space limitations do not allow for drainage ditches.

Sub-drain infrastructure must be designed and located to facilitate maintenance and reduce the possibility of clogging. Sub-drain cleanouts must be provided at all high points/low points and at a maximum spacing of 140 m with outlets to the minor system at all low points.

Sub-drains must be sized to contain the 1:25-year design event. The minimum size of sub-drain pipe must be 200 mm in diameter and the minimum slope must be 0.30%.

A non-woven geotextile fabric must wrap around the sub-drain system to prevent infiltration of clay or silt into the system.

Sub-drain outlets are to be provided at Trackway low points, upstream of intersections and upstream of track type transitions.

Ballast drainage requires buffering of peak flows prior to release into the minor drainage system at a rate of the 1:5-year pre-development event or a flow rate defined by the Engineer.

16.4.4.2 Embedded Track Drainage

The Trackway drainage system must properly drain track flangeways. Track drains must be located at low points and at the upstream sides of intersections and crosswalks and at intermediate track intervals of no greater than 50 m. Drainage should be provided for every recess in the Trackway, including but not limited to track switches, switch machines, lubricators, and switch blowers.

Infiltration drains must be installed running parallel to the track to intercept groundwater infiltration. Infiltration drain cleanouts to be provided at all high points/low points and at a maximum spacing of 140 m with outlets to the minor system at all low points and every 140 m.

Snow pile zones are not permitted next to embedded track unless measures are taken to prevent snowmelt from draining towards the Trackway.

16.4.4.3 Direct Fixation Track Drainage

The Designer must be aware of the possibility that sections of direct fixation track that have a Trackway base at a lower elevation than the surrounding ground may cause water to be impounded. Sunken direct fixation sections of track will require a drainage overflow point to maintain a water level below the TOR.

Infiltration drains must be installed running parallel to the track to intercept groundwater infiltration. Infiltration drain cleanouts to be provided at all high points/low points and at a maximum spacing of 140 m with outlets to the minor system at all low points and every 140 m.

16.4.4.4 Special Trackwork Drainage

Infiltration drains must be installed running parallel to the track to capture groundwater infiltration under embedded or direct fixation track.

Special trackwork on direct fixation and embedded track types requires positive drainage to track drain inlets for ROW equipment.

16.4.4.5 At-Grade Crossing Drainage Considerations

At-Grade LRT crossings of roads and pedestrian crosswalks must as a minimum match the general approach grade and should be slightly higher than the approach to promote positive drainage away from the crossing area. The approaches should be ramped up to match the crossing.

At-Grade crossings must be adequately drained. Infiltration drainage pipe is required parallel to the Trackway running underneath the road crossing and connecting to either the drainage system or stand-alone reservoirs if required.

Non-woven geotextile should be provided under At-Grade crossings of tie and ballast track to direct water toward the sub-drains and prevent migration of clay or silt upward into the ballast layer.

16.4.4.6 Tunnel, Underpass and Below-Grade Structure Drainage Considerations

Stormwater runoff from any tunnel or underpass must be addressed for events up to and including the 1:100-year design event. This may include conveyance, capture, control and treatment. The Designer must review the requirements with the Engineer on a case-by-case basis.

The Designer must assume that underground structures cannot be completely waterproofed, and that water infiltration will occur. Water infiltration through roofs and side walls must be controlled through the provision of infiltration drains and pressure relief weep drains near Trackway level and a drainage layer must be provided behind walls to mitigate the buildup of hydrostatic pressure.

Stormwater runoff from events up to and including the 1:100-year design event must be prevented from entering any below-grade Trackway. Collected runoff must be conveyed by gravity to the minor stormwater system, unless a stormwater lift station is required and is accepted by the Engineer in consultation with the Operator.

The stormwater management system within an LRT tunnel must be designed to accommodate stormwater in excess of the capacity of the stormwater inlet at the tunnel entrance, meltwater from drifted snow and off LRVs, groundwater seepage, and wash water. Tunnel emergency access shafts must be protected from ingress of surface water. Measures must be employed to divert surface water away from the access hatches into the drainage system.

Sufficient slope towards discharge points is required to prevent standing water on LRT and pedestrian/cyclist underpasses and tunnels.

Lift stations and sump pumps are only permitted where gravity flow cannot be achieved. Their installation will require the prior acceptance by the Engineer in consultation with the Operator. If lift stations are to be installed, they must meet the requirements provided in the D&CS.

Sanitary drainage is not permitted to enter the Trackway.

If necessary, backflow preventers and other suitable measures to protect a facility or installation from water intrusion should be provided.

16.4.4.7 Bridge, Overpass, and Guideway Drainage Considerations

Stormwater runoff from any bridge or guideway must be addressed for events up to and including the 1:100-year design event. This may include conveyance, capture, control and treatment. The Designer must review the requirements with the Engineer on a case-by-case basis.

Flow from stormwater management inlets may be directed into the minor drainage system or discharged onto surface areas not designated for regular pedestrian use such as roadway gutters or vegetated areas, but must minimize impacts on the public.

Wherever stormwater is discharged directly onto surface areas, energy dissipation measures are required to prevent erosion.

Stormwater runoff from bridges, guideways and aerial structures must be routed through grit traps sized to contain all grit from events up to and including the 1:5-year design event prior to being discharged to the minor drainage system or the natural environment. Stormwater management control is required for events up to and including the 1:100-year design event.

Sufficient slope towards discharge points is required to prevent standing water from occurring on overpasses, bridges and the Trackway.

16.4.4.8 Operation & Maintenance Considerations of Drainage Infrastructure

The drainage Design should analyze ownership, O&M, and access of storm drainage infrastructure to optimize the design.

16.4.5 Streets Drainage

Volume 3 of the D&CS [269] provides the Designer with the City standards related to the drainage requirements for Streets. The D&CS also include clauses for a variety of drainage related appurtenances, such as catch basins, manholes, and culverts.

16.4.6 Drainage of LRT Related Areas

16.4.6.1 Stations and Ancillary Facilities

Positive drainage away from all foundations is required. Ramps and stairs should include a drainage area, such as a trench drain, at the base of the ramp to trap grit, water and snowmelt. The Designer should consider the installation of engineered prefabricated drain systems.

Platforms in underground tunnels or inside covered facilities may have a flat finished surface with no crossfall. Platforms that are open to the environment and subject to snow and rainfall must have a finished surface cross slope of 1.5% sloping towards the tracks. A centre-loading Platform must be crowned longitudinally from the midpoint of the Platform.

Tie and ballast track along Platform sections that are open to the environment and subject to snow and rainfall must have perforated drainage pipes located along the inside of the Station wall or along the base of the Platform to divert stormwater runoff from the Platform away from the Station footprint.

16.4.6.2 Overhead Contact System Poles

Water stop joints are required for any cuts in a concrete Trackway slab, such as around the bases of Overhead Contact System (OCS) poles.

16.4.6.3 Systems – Duct Banks/Vaults

Duct banks and vaults must have provisions for drainage of inflowing or infiltrating stormwater. Vault floors are to be sloped towards a drain. Drainage should be by gravity directly into the minor storm sewer system with a low maintenance and low flow backflow preventer.

16.4.6.4 Building/Mechanical Drainage

Refer to Chapter 12, Mechanical for building drainage and servicing requirements.

16.4.6.5 Operations and Maintenance Facilities

All stormwater runoff from an OMF must be managed on-site for all rainfall design events as directed by the Engineer.

Discharge to the minor drainage system is to be controlled to the lesser of 35.0 L/s/ha over the OMF site, or the maximum allowable discharge rate to prevent overloading of the existing stormwater management systems receiving the flow as directed by the Engineer.

APPENDIX 16A – UTILITY LOCATION CRITERIA PARALLEL TO AND CROSSING THE LRT ROW

Utility	Depth (To Top Of Utility)	Parallel Clearance	Crossing Clearance	Crossing Protection
Storm Sewers Sanitary Sewers Combined Sewers	0 – 7 m	• Minimum 2.0 m from edge of LRT ROW to edge of pipe. • May be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a case-by-case basis. • MHs/CBs/Appurtenances must be relocated to meet minimum clearance requirements. • Minimum 3.0 m clearance from tunnel/underpass walls to edge of pipe.	• Minimum 2.0 m from top of rail to pipe obvert. • Pipe must be protected from freezing.	• Pipes to be cased a minimum of 6.0 m beyond the track centreline unless greater than 750 mm diameter Pressure pipes to be cased a minimum of 6.0 m beyond the track centreline. • All pipes to avoid crossing Platforms, otherwise they must be cased and avoid conflicts with the Platform foundation.
Storm Sewers Sanitary Sewers Combined Sewers	> 7 m	• No pipe offset required for At-Grade Trackway subject to approval by the Engineer. • Minimum 3.0 m clearance from tunnel/underpass walls to edge of pipe • MHs/CBs/Appurtenances must be relocated to meet minimum clearance requirements.	• Must meet minimum crossing clearance (above).	• Not required. • All pipes to avoid crossing Platforms, otherwise they must be cased and avoid conflicts with the Platform foundation.
Water	All	• Minimum 2.0 m from edge of LRT ROW to edge of pipe. • May be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a	• Minimum 2.0 m from top of rail to pipe obvert. • Pipe must be protected from freezing.	• Casing required for all pressure pipes and services for a minimum of 6.0 m beyond the track centreline. • All pipes to avoid crossing Platforms, otherwise they must be cased

Utility	Depth (To Top Of Utility)	Parallel Clearance	Crossing Clearance	Crossing Protection
		case-by-case basis. • Hydrants/Valves/ Appurtenances must be relocated to meet minimum clearance requirements. • Minimum 3.0 m clearance from tunnel/underpass walls to edge of pipe.		and avoid conflicts with the Platform foundation.
Natural Gas	All	• Existing infrastructure to be located a minimum of 1.0 m from edge of LRT ROW to centreline of pipe. • New or relocated infrastructure to be located a minimum of 1.5 m from edge of LRT ROW to centreline of pipe. • May be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a case-by-case basis. • Appurtenances must be relocated to meet minimum clearance requirements.	• Minimum 1.83 m from top of rail to pipe obvert.	• Casing of gas infrastructure is not required, but if casing is used it must be non-conductive, continuous, and extend a minimum of 6.0 m beyond track centreline on both sides of the LRT ROW.
Underground Power Distribution Infrastructure	All	• Existing infrastructure to be located a minimum of 1.0 m from edge of LRT ROW to centreline of utility. • New or relocated infrastructure to be located a minimum of 1.5 m from edge	• Minimum 1.83 m from top of rail to utility.	• Utility must be in conduit for crossing and must be non-conductive, continuous, and extend a minimum of 6.0 m beyond track centreline.

Utility	Depth (To Top Of Utility)	Parallel Clearance	Crossing Clearance	Crossing Protection
		of LRT ROW to centreline of utility. • May be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a case-by-case basis. • Appurtenances must be relocated to meet minimum clearance requirements. • Power easements must not extend into the LRT ROW.		
Underground Power Transmission Infrastructure	All	• Must be evaluated for relocation through discussions with the utility provider and the Engineer on a case-by-case basis.	• Must be evaluated for relocation or protection through discussions with the utility provider and the Engineer on a case-by-case basis.	• Must be evaluated for relocation or protection through discussions with the utility provider and the Engineer on a case-by-case basis.
Underground Telecommunication Infrastructure	All	• Existing, relocated or new infrastructure to be located a minimum of 1.0 m from edge of LRT ROW to centreline of utility. • Appurtenances must be relocated to meet minimum clearance requirements.	• Minimum 1.83 m from top of rail to utility.	• Utility must be in conduit for crossing and must be non-conductive, continuous, and extend a minimum of 6.0 m beyond track centreline.
Pipelines	All	• Coordination required between pipeline owner and Engineer to define clearance on a case-by-case basis. • Pipeline infrastructure is not permitted	• Coordination required between pipeline owner and Engineer to define clearance on a case-by-case basis.	• Must be suitably protected as defined by the pipeline owner and Engineer.

Utility	Depth (To Top Of Utility)	Parallel Clearance	Crossing Clearance	Crossing Protection
		within the LRT ROW or Urban Interface zones.		
Overhead Utilities (Power Distribution, Transmission and Telecommunication Infrastructure)	N/A	• Minimum of 9.0 m from centreline of track to utility poles for distribution power and telecommunications infrastructure. • Transmission power lines to be evaluated for clearance requirements through discussions with the utility provider and the Engineer on a case-by-case basis. • Must be located outside of the Urban Interface zone.	• Must be evaluated for clearance requirements through discussions with the utility provider and the Engineer on a case-by-case basis.	N/A
Cellular Towers	N/A	• Cellular towers should be located outside of the Transportation Corridor. • Cellular towers must be assessed through discussions with the utility provider and the Engineer on a case-by-case basis.	N/A	N/A

CHAPTER 17

Streets

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INTENT OF USE

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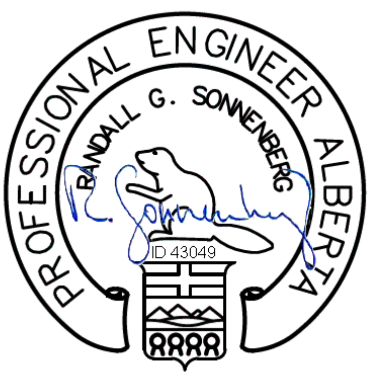

29-Mar-2022

Permit to Practice

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STANTEC CONSULTING LTD.
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The Association of Professional Engineers and Geoscientists of Alberta

17 STREETS

17.1 INTRODUCTION

This chapter presents guidelines for concept planning, preliminary Design, and detailed Design of Streets and streetside facilities that are impacted by operation of and integration with the Light Rail Transit (LRT) System. These guidelines relate to Design considerations that are specific to LRT interfaces for Streets adjacent to the LRT Right-of-Way (ROW) and to LRT integration where Streets cross the LRT ROW At-Grade.

For Streets that run parallel to the LRT ROW, this chapter provides guidance for design of the interface between the LRT ROW and the adjacent roadway or pedestrian/bicycle facilities. Geometric design of adjacent Streets is based on the most current applicable standards and guidelines listed in 17.1.2.

For Streets that cross the LRT At-Grade, this chapter provide guidance for design of the crossing areas for all modes. Chapter 10, Stations and Ancillary Facilities and Chapter 14, Urban Integration provide guidance on the type and intent of the crossings.

17.1.1 Applicable Codes, Standards, and Regulations

The following reference manuals apply to this chapter:

- A Policy on Geometric Design of Highways and Streets [272]
- Access Design Guide [258]
- Access Management Guidelines [273]
- Accessible Design for the Built Environment [274]
- Barrier-Free Design Guide [14]
- Bikeway Traffic Control Guidelines for Canada [275]
- Canadian Capacity Guide for Signalized Intersections [276]
- Canadian Guide to Neighbourhood Traffic Calming [277]
- Canadian Roundabout Design Guide [278]
- City of Edmonton Complete Streets Design and Construction Standards [153]
- Traffic Bylaw 5590 [279]
- City of Edmonton Zoning Bylaw 12800 [280]
- Creating Safer Communities [198]
- Design Vehicle Dimensions for Use in Geometric Design [281]
- Geometric Design Guide for Canadian Roads [282] and Urban Supplement [283]
- Grade Crossing Standards [64]
- Guide for Maintaining Pedestrian Facilities for Enhanced Safety [284]
- Guide for the Design of Roadway Lighting [285]
- Guide for the Development of Bicycle Facilities [286]
- Highway Geometric Design Guide [287]
- Human Factors Research in Highway Safety, Transportation Research Board
- Main Streets Guideline [288]
- Manual of Uniform Traffic Control Devices for Canada [289]
- Metric Curve Tables: Circular and Spiral Curve Functions for Layout Purposes [290]
- Pedestrian Crossing Control Guide [291]
- Roadside Design Guide [292]

- Separated Bike Lane Planning and Design Guide [293]
- Winter Design Guidelines [294]

17.2 DESIGN CONSIDERATIONS WHEN ADJACENT TO LRT

17.2.1 Private and Commercial Crossings

Pre-existing crossings that will be impacted by LRT operations must be replaced in-kind or be modified or relocated in consultation with affected stakeholders. Modification and relocation of crossings must be accepted by the Engineer. Permanent removal of crossings will require City Council approval of a closure bylaw.

17.2.2 Bus Stops

For all bus routes adjacent to or crossing the LRT ROW, bus stops must be located as close as practicable to Stations. Connections from bus stops to Stations must be hard surfaced and provide access for pedestrians of all abilities. Bus stops on single lane roadways should be in laybys as high numbers of Patrons moving to or from the Stations are expected. Locations, dimensions and arrangement of bus stops will be determined by the Engineer in consultation with the Operator. To enhance provision of replacement bus service during LRT service disruptions, bus stops should be visible from Stations and within 100 m walking distance.

17.2.3 Clearance Requirements (From LRT Delineation to Edge of Street)

Clearance requirements, offsets, or shy distances from LRT delineation facilities and barriers to edge of the adjacent Street must be designed in accordance with the Geometric Design Guide for Canadian Roads [282]. The Designer must also consider snow storage requirements adjacent to roadways and bicycle or pedestrian facilities when evaluating offsets.

17.3 LRT AT-GRADE CROSSINGS

For defined, legal crossings of the LRT ROW At-Grade, this section provides guidance for design of the crossing areas for integration of all modes crossing the LRT ROW.

At-Grade crossings of the LRT ROW may be at roadway intersections, where all modes are able to cross, or at designated pedestrian and/or bicycle crossing locations not associated with a motor vehicle crossing.

Minimum crossing warning measures that must be implemented at At-Grade crossings are provided in the Transportation Corridor & Operations Matrix in Chapter 1, General which provides requirements for active warning systems and passive controls. Active warning systems change state based on presence of a Light Rail Vehicle (LRV), while passive warning measures advise pedestrians, cyclists and/or motorists of an LRT crossing without information on the presence of an LRV.

All motor vehicle crossings of the LRT ROW must be controlled with an active warning system. Refer to Chapter 7, Signals for details. Gates, flashing lights, and bells are examples of active warning systems, along with traffic or pedestrian signals that are linked to the Signaling System to prohibit motor vehicle, bicycle, and pedestrian movements when a Train is present or approaching.

Static signage, bollards, and tactile zones are examples of passive warning measures. Although passive measures can be used independently, the Designer must consider appropriate use of passive measures in conjunction with the design of all active warning systems.

The Designer must consider adjacent and nearby land uses, motor vehicle, cyclist, and pedestrian volumes, user demographics, and sight lines in the design of all At-Grade crossings. An awareness of existing practices for the design of At-Grade crossings for LRT systems similar to the Edmonton LRT System and industry standard documents such as Transit Cooperative Research Program (TCRP) reports must also be considered in the design of At-Grade crossings. Crossing geometry design and type of protection should be consistent along the Transportation Corridor and accommodate safe crossings for pedestrians of all ages and abilities. Crosswalks at Station locations must be assessed based on a combination of pedestrian and Patron volumes to determine if additional width over minimum standards is required.

17.3.1 Passive Warning Measures for Pedestrian and/or Bicycle Crossings

Where practicable, the Designer should use ‘Danish’ or ‘Z’ style crossings which provide a refuge area and promote user awareness of LRVs travelling on either track. If this style of crossing is not practicable, the Designer must use swing gates and include a clear zone/refuge area between the gates and the Trackway.

Tactile warning measures must be resistant to damage from snow clearing activities, and the Designer must consider the possibility that tactile warning areas may not be perceivable to users during winter conditions.

The Designer must implement specific signage to warn users of the possibility that a second Train in the opposite direction may arrive as the first Train is passing.

17.3.2 Active Warning Measures for Pedestrian and/or Bicycle Crossings

If crossing arms are chosen as part of an active warning system, the Designer must allow clearance from the crossing arms to the adjacent Street to create a pedestrian/bicycle refuge area. An escape gate must be provided to allow pedestrians and cyclists to exit the Trackway after the crossing arms have descended.

As appropriate, pedestrian (Walk/Don’t Walk) or bicycle (Green Bike/Red Bike) Signals may be used as the primary form of active control at a crossing. The Designer must consider additional visual cues to enhance user awareness of an approaching LRV, particularly in areas where users are likely to be inattentive.

The Designer must include accessible pedestrian controls that consider needs of visually impaired users.

Specific visual cues for a second Train warning, in addition to base active warning measures, must be implemented wherever practicable.

Design of an active warning system must always include use of appropriate passive warning measures.

17.3.3 Active Warning Measures for Street Crossings of the LRT Right-of-Way

The Designer must allow clearance from crossing arms, if present, to the adjacent Street to create a pedestrian/bicycle refuge area. In addition to the pedestrian Signals at a Street crossing, the Designer should consider additional visual cues to enhance user awareness of an approaching LRV.

If crossing arms are not chosen as part of an active warning system, specific visual cues for second train warning, in addition to the base active warning measures, must be implemented.

Protected/prohibited left turn traffic signal phases must be provided for roadways parallel to a center-running LRT ROW, and for left turns that cross a side-running LRT ROW. Left turn signals for roadways crossing an LRT ROW may require protected or protected/prohibited phases. Overlapping left turns may be permitted in constrained corridors, however split left turn phasing must be provided.

A side running LRT ROW must have full traffic signal control at all right turn crossings, both parallel and perpendicular to the Trackway. The Design must include either permanent or active right turn on red prohibition.

The Designer must consider the impact of queuing motor vehicles that may conflict with LRT crossings.

Design of an active warning system must always include use of appropriate passive warning measures.

17.4 EMERGENCY AND MAINTENANCE VEHICLE ACCESS

The Design must allow maintenance workers and emergency responders to access the Trackway, Stations and Ancillary Facilities, and adjacent properties. The Design must provide emergency responder access points along the LRT ROW and there must be, at minimum, one access point between Stations along elevated, trenched, or tunneled sections.

17.4.1 Emergency Response

For a centre running LRT ROW, emergency vehicles must not be impeded in single-lane sections of a Street by queued traffic or by disabled vehicles blocking a traffic lane. The Design must allow for emergency vehicles to bypass a blocked lane on a roadway boulevard or within the Urban Interface zone, or must make allowance for emergency vehicles to drive on or across the Trackway. Areas of roadway boulevard or Urban Interface zone intended for emergency vehicle bypass must allow for all-weather trafficability, be free of street furniture and trees or shrub beds, and must be designated as an area where snow may not be stored.

If primary access to titled parcels by Fire Rescue Services (FRS) is from a Transportation Corridor containing an LRT ROW, then a minimum 6.0 m hard-surfaced and unobstructed zone between the Trackway and the property line of the adjacent parcels must be provided to allow setup of FRS equipment for firefighting.

17.4.2 Maintenance and Operations

The Designer must provide access and parking for Service Vehicles at Stations, Traction Power Substations (TPSS), Utility Complexes, and at the ends of elevated structures for scheduled and emergency maintenance and operational activities. Parking requirements are provided in Chapter 10, Stations and Ancillary Facilities. Access from parking stalls to an adjacent Street must be provided. Parking areas must be hard surfaced to provide all-weather access.

Maintenance of special trackwork in an At-Grade LRT ROW requires motor vehicle access near switch locations. A parking area that is a minimum of 6.0 m long and 2.5 m wide is required within 50 m of the farthest switch point. Access to this parking area must be hard surfaced to provide all weather access but may be separated from the adjacent Street by roadway curbs. The parking area must have access to the Trackway that is not unduly constrained by hard or soft barriers.

Snow that is cleared from a Street adjacent to the LRT ROW must not be stored within the LRT ROW. The Designer must consider opportunities to store snow in roadway boulevards or within the Urban Interface zone to minimize the need for snow removal from the Transportation Corridor.

CHAPTER 18

Acronyms

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18 LIST OF ACRONYMS

Acronym	Meaning
AAA	Alberta Association of Architects
AAC	Accessibility Advisory Committee
AAR	Association of American Railroads
ABC	Alberta Building Code
AC	Alternating Current
ACB	Axle Counter Blocks
ACH	Air Change per Hour
ADA	Americans with Disabilities Act
AEDARSA	Alberta Elevating Devices and Amusement Ride Safety Association
AFC	Alberta Fire Code
AFRRCS	Alberta First Responders Radio Communications System
AFF	Above Finished Floor
AFTC	Audio Frequency Track Circuits
AHJ	Authority Having Jurisdiction
AIM	Advanced Information Management
AIR	Air Systems Monitoring
ANSI	American National Standards Institute
APEGA	Association of Professional Engineers and Geoscientists of Alberta
API	Application Programmers Interface
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance Association
ASCA	Alberta Safety Code Act
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASPE	Standards American Society of Plumbing Engineers
ASTM	American Society for Testing and Materials
ATM	Automatic Teller Machines
ATP	Automatic Train Protection
ATS	Automatic Transfer Switch
AW	Added Weight
AWG	American Wire Gauge
BCP	Best Common Practice
BER	Bit-Error-Rate
BICSI	Building Industry Consulting Services International
BLC	Blacklight Compensation
BLR	Boiler Monitoring and Control

BLSR	Bi-directional Line Switched Ring
BMS	Building Management System
BWA	Balance Weight Assembly
CAB	Cold Air Blowers
CAC	City of Edmonton Corporate Accessibility Committee
CADD	Computer Aided Design & Drafting
CADPM	Communications AC and DC Power Module
CAT	Category (designates cable category standard)
CCD	Charge Coupled Device
CCTV	Closed Circuit Television
CDP	Central Distribution Panel
CEC	Canadian Electrical Code
CEF	Cable Exchange Forces
CHBDC	Canadian Highway and Bridge Design Code
CIE	Common Infrastructure Environment
CLF	Cable Loss Forces
CLG	Cooling Systems Monitoring and Control
COE	City of Edmonton
CoP	Communication on Progress
CMO	Carbon Monoxide Condition Monitoring
CPTED	Crime Prevention Through Environmental Design
CSA	Canadian Standards Association
CSDCS	Complete Streets Design and Construction Standards
CTC	Centralized Train Control
CUCM	Cisco Unified Communication Management
CWAT	Contact Wire Auto Tension
CWDM	Course Wave Division Multiplexing
CWI	Crossing Warning Indicator
CWR	Continuous Welded Rail
D&CS	City of Edmonton Design and Construction Standards
DA	Directory Access
DAS	Distributed Antenna System
DATP	Discrete-point Automatic Train Protection
DATS	Disabled Adult Transit Service
DBM	Design Basis Memorandum
DC	Direct Current
DDC	Direct Digital Control
DLA	Dynamic Load Analysis
DLM	D.L. MacDonald

DMVPN	Dynamic Multipoint Virtual Private Network (DMVPN) technology
DQMP	Design Quality Management Plan
DSD	Design Services Document
DSP	Digital Signal Processing
DVR	Digital Video Recorder
DVSE	Design Vehicle Static Envelope
DVDE	Design Vehicle Dynamic Envelope
EASE	Enhanced Acoustic Simulator for Engineers
EC	Electronically Commutated
EDACS	Enhanced Digital Access Communication System
EEMAC	Electrical Equipment Manufacturer Association of Canada
ELC	Electrical Systems Monitoring
ELV	Elevator Monitoring and Control
EMBC	Electronic Monitoring Bleed Control
EMC	Electromagnetic Compatibility
EMCS	Energy Management and Control System
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EMS	Emergency Medical Services
EMT	Electrical Metallic Tubing
ETS	Edmonton Transit Service
ETSI	European Telecommunications Standards Institute
FAS	Fire Alarm System
FBS	Fixed Block System
FDH	Fibre Distribution Housing
FEP	Fluorinated Ethylene Propylene
FIR	Fire Suppression Systems Monitoring
FMR	Feeder Management Relay
FMS	Facility Management Services
FOSC	Fibre Optic Splice Closure
FPS	Frames Per Second
FRS	Fire Rescue Services
FRSC	Fire Signal Receiving Centre
FT	Fixed Tension
GAS	Natural Gas System Monitoring and Control
GbE	Gigabit Ethernet
GBIC	Gigabit Interface Converter
GCWS	Grade Crossing Warning System
GEN	Generator Systems Monitoring

GEX	General Exhaust Systems Monitoring and Control
GLY	Glycol Heating Systems Monitoring and Control
GOE	Government of Alberta
GSC	Genetec Security Centre
GUI	Graphic User Interface
HDPE	High Density Polyethylene
HEPA	High Efficiency Particulate Air
HID	High Intensity Discharge
HLC	Highlight Compensation
HMI	Human Machine Interface
HTG	Heating Systems Monitoring and Control
HVAC	Heating Ventilation Air Conditioning
HWx	Heating Water Systems Monitoring and Control where “x” = system numbers
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFC	Issued for Construction
IFT	Issued for Tender
IP	Internet Protocol
LCP	Local Control Panel
LDAP	Lightweight Directory Access Protocol
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LOS	Level-of-Service
LRT	Light Rail Transit
LRV	Light Rail Vehicle
LSZH	Low-Smoke, Zero-Halogen
LTG	Lighting System Monitoring and Control
MBR	Maximum Bit Rate
MC	Marshalling Cabinet Monitoring
MDP	Main Distribution Panel
MPA	Mid-Point Anchor
MPLS	Multi-Protocol Label Switching
MRC	Manual Route Clearance
MSE	Mechanically Stabilized Earth
MV	Medium Voltage
NAS	Network Attached Storage
NB	Northbound
NBC	National Building Code of Canada

NCF	Negative Circuit Feeder
NCR	Non-Conformance Report
NECB	National Energy Code of Canada for Buildings
NEXT	Near End Crosstalk (Loss)
NFC	National Fire Code
NFPA	National Fire Protection Association
NPC	National Plumbing code of Canada
NVR	Network Video Recorder
O & M	Operations and Maintenance
OAT	Outdoor Air Condition Monitoring
OCC	Operations Control Centre
OCS	Overhead Contact System
OFR	On-Frequency Repeaters
OHSA	Occupational Health and Safety Act
OMF	Operations and Maintenance Facility (Facilities)
OOB	Out of Band
OSDI	On-Screen Directional Indicator
OSE	Optical Splice Enclosure
OSP	Outside Plant
OTPS	Overhead Traction Power System
OWS	Operator Work Station
PA	Public Address
PCoIP	PC-over-IP
PDC	Power Distribution Centre
PDDM	Project Development and Delivery Model
PDU	Protocol Data Unit
PDS	Power Distribution System
PE	Polyethylene
PLC	Programmable Logic Controller
PMG	Permanent Magnet Generator
PoE	Power Over Ethernet
POT	Portable Operator Terminal
PSTN	Public Switched Telephone Network
PSU	Power Supply Unit
PTZ	Pan, Tilt, Zoom Camera
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance / Quality Control
QoS	Quality of Service

RADIUS	Remote Authentication Dial-In User Service
RAMS	Reliability Availability Maintainability and Safety
RFI	Requests for Information
RGS	Rail Ground Switch
ROW	Right-of-Way
RRS	Radio Repeater System
RSC	Rigid Steel Conduit
RSSI	Received Signal Strength Indicator
RTRC	Reinforced Thermosetting Resin Conduit
RTU	Remote Terminal Unit
SAN	Storage Area Network
SB	Southbound
SCA	SCADA System Alarm Monitoring.
SCC	Switch Circuit Controller
SCADA	Supervisory Control and Data Acquisition
SCAT	Simple Catenary Auto Tension
SCN	Survey Control Network
SCP	Supervisory Control Panel
SEC	Security and Alarm Monitoring Systems
SEM	Sequential Excavation Method
SER	Signal Equipment Room
SFP	Small Form-Factor Pluggable
SFV	Smart Fare Validator
SFVM	Smart Fare Vending Machine
SIL4	Safety Integrity Level 4
SIP	Session Initiation Protocol
SLS	Serviceability Limit States
SMK	Smoke Control Monitoring and Control
SMP	Sump Monitoring
SNW	Track Snow Blower Monitoring and Control
SOP	Safe Operating Procedure
SORS	Sequential Occupancy Restoral System
SPK	Speaker
SPT	Space Temperature Monitoring
SRR	Signals Room Routers
SRS	Signals Room Switch
SSD	Surge Suppression Devices
STI	Speech Transmission Index

SUI	Sustainable Urban Integration
SUP	Shared Use Path
TAC	Transportation Association of Canada
TBM	Tunnel Boring Machine
TCGCS	Transport Canada Grade Crossing Standards
TCO	Total Cost of Ownership
TCRP	Transit Cooperative Research Program
TEL	Telephone
TGB	Terminal Ground Bus
THD	Total Harmonic Distribution
TIA	Telecommunications Industries Associations
TO	Train Operator
TOD	Transit Oriented Development
TOR	Top of Rail
TP	Traction Power
TPS	Traction Power System
TPSS	Traction Power Substation
TRR	Territory Ring Routers
TRS	Territory Ring Switch
TTY	Text telephone for the hearing impaired
TVM	Ticket Vending Machine
TVV	Ticket Vending Validator
TWSI	Tactile Walking Surface Indicators
UC	Utility Complex
ULA	Utility Line Assignment
ULC	Underwriter's Laboratories of Canada
ULS	Ultimate Load States
U of A	University of Alberta
UPS	Uninterruptable Power Supply
UPSR	Unidirectional Path Switched Ring
US DOT	United States Department of Transportation
USP	Universal System Platform
UTNP	Urban Traffic Noise Policy
UV	Ultra-Violet
VBR	Variable Bit Rate
VDA	Video Distribution Amplifier
VDE	Verband Deutscher Electrotechniker
VFD	Variable Frequency Drive

VGW	Voice Gateway
VLC	Vital Logic Controller
VLD	Voltage Limiting Device
VLT	Vault Monitoring
VMS	Variable Message Sign
VNC	Virtual Network Computing
VoIP	Voice over Internet Protocol
VOV	Verband Öffentlicher Verkehrsbetriebe
VPLS	Virtual Private LAN Service
VPRN	Virtual Private Routed Network
VRCE	Vehicle Running Clearance Envelope
VRF	Virtual Routing and Forwarding
WAP	Wireless Access Point
WBS	Wireless Base Station
WDM	Optical Wave Division Multiplexor
WSU	Wireless Subscriber Unit

CHAPTER 19
Definitions

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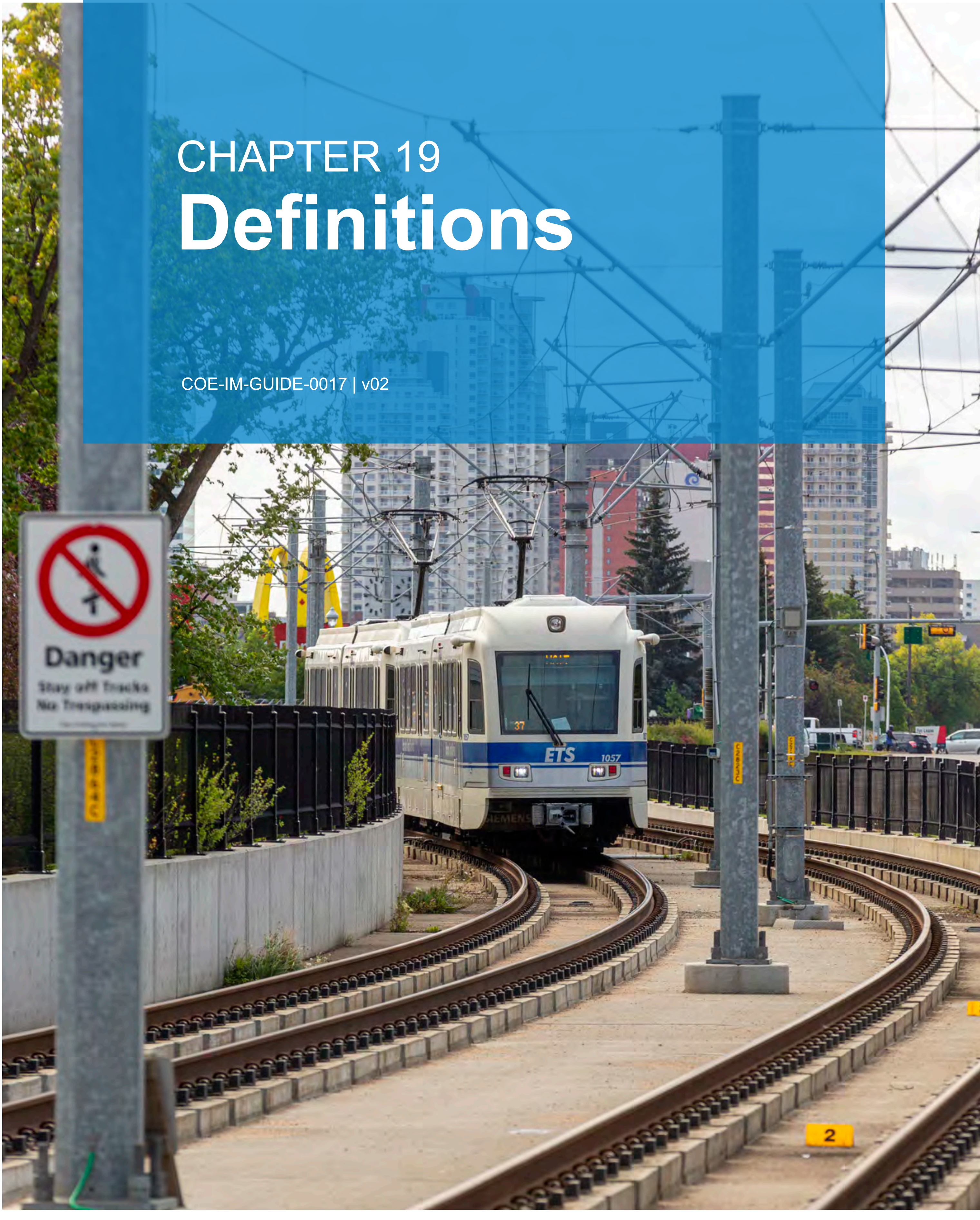

19 LIST OF DEFINITIONS

Term	Definition
Access Design Guide	A City of Edmonton document that provides information on creating accessible environments, supported by City of Edmonton Policy C602.
Accessibility	The absence of barriers that prevent individuals and/or groups from fully participating in all social, economic, cultural, spiritual and political aspects of society. The term also refers to rights to access, and to universal design characteristics of products, devices, information, programs, services, infrastructure that enable independent use, or support when required, and access by people with a variety of disabilities.
Ancillary Facilities	Buildings or structures that support the function and operation of the LRT System. These may include: • Pedestrian overpass or underpass structures (pedways) • Passenger shelter structures • Structures containing mechanical, electrical, communications or other service equipment • Traction Power Substations or Utility Complexes • Signal equipment enclosures • Transit Centre buildings (shelters) • Parking areas (surface and in structure)
Application Logic	A collection of Boolean expressions and relationships which replicate relay logic circuits within a solid-state Vital Logic Controller.
At-Grade	The cross-sectional form of the Trackway where the elevation of the Trackway is at the same relative elevation as the adjacent ground level.
Authority Having Jurisdiction	An accredited municipality, an accredited regional services commission or an accredited corporation that is responsible the administration of under the Alberta Safety Codes Act. This definition shall include the Authority Having Jurisdiction's duly authorized representative.
Barrier-Free	Absence of obstacles, allowing persons with physical, cognitive or sensory impairments safer or easier, access to pathways, open spaces, amenities, facilities, services, or activities.
Barrier-Free Design Guide	A design guide respecting the minimum building requirements for disabled persons in the most current Alberta Building Code in force in the Province of Alberta.

Block Signal	A Signal that governs the entrance to a Signal Block or Interlocking and conveys authority to proceed into the next Signal Block.
Bond	A metal conductor, usually copper, connecting two points of a conductive structure to equalize their electrical potential.
Building Management System (BMS)	Direct Digital Control system complete with hardware, software, and graphics for control of equipment, systems, and environment within a building or structure.
Call-on Signal	A Signal which conveys information about the status of a crossing warning system.
Canopy	The overhead covering or roof-like structure that provides shelter for Patrons on a Platform from rain, sun, or snow.
Catwalk	A structural element which provides a safe area for maintenance personnel during LRT System operation and functions as a Designated Egress Walkway for LRV Passengers during an emergency.
Concourse	An intermediate area connecting a station Platform to a Street via stairs, escalators, or corridors.
Conductive Structure	Infrastructure that conducts electricity or has components that can conduct electricity and are susceptible to the effect of corrosion and stray current (e.g. metal infrastructure, concrete infrastructure with reinforcing steel, metallic pipe or conduit).
Consist	One or more rail vehicles, at least one of which must be powered, forming a complete Train.
Contract Documents	Drawings, specifications and other documents that relate specifically to an individual project.
Contractor	An entity that is employed by the Engineer to construct LRT infrastructure. The Contractor may employ the Designer depending on the project delivery method.
Control Block	A section of Trackway consisting of one or more Signal Blocks bounded by Interlockings.
Crime Prevention Through Environmental Design (CPTED)	The science around the design and effective use of physical space to lead to a reduction in both the incidence and fear of crime.
Cross Bond	An electrical connection between parallel conductors of the Return Circuit intended to promote current balance between adjacent tracks and each running rail.

Cross-Connections	Tunnel segment between two structures, usually two tunnels. A Cross-Connection is used by ETS personnel and by LRV Passengers in an emergency.
Curvature Effect	Vehicle body overhang induced by a curve. This effect is considered independently of other effects on the dynamic envelope.
Design	The drawings, specifications and other necessary detailed information to enable the Contractor to complete construction of LRT infrastructure including: • Concept planning • Preliminary Design • Detailed Design • Issued-for-construction drawings • Supporting calculations or reports
Designer	An entity (or its subconsultants) that is employed by the Engineer or Contractor, depending on project stage and delivery method, to develop high-floor LRT Designs for their intended purpose. The Designer must be registered to practice with a relevant professional association, such as AAA (the Alberta Association of Architects) or APEGA (the Association of Professional Engineers and Geoscientists of Alberta).
Design Headway	Theoretical minimum headway of the Signal System.
Design Vehicle Dynamic Envelope (DVDE)	Maximum space occupied by the Design vehicle under dynamic conditions taking into account vehicle movements on a level tangent track.
Design Vehicle Dynamic Outline	Plan view representation of truck spacing and vehicle overhang. This outline is required for determining the curvature effects on clearances for all mainline infrastructure (except for the Catwalk in tunnels).
Design Vehicle Running Clearance Envelope	Space occupied by the Design Vehicle Dynamic Envelope plus additional dynamic clearance requirements (as applicable) for curvature effects, trackwork installation, maintenance tolerance, and structural clearances.
Design Vehicle Static Envelope	The physical cross-sectional dimensions of the Design vehicle that accommodate all on-track vehicles used by the Operator.
Designated Egress Walkway	A pathway within the LRT ROW or Grade Separated structure that provides for the safe movement of ETS personnel or Patrons in an emergency. The Designated Egress Walkway is defined by horizontal and vertical limits.

Disabilities	An umbrella term covering impairments, activity limitations, and participation restrictions which can be physical, cognitive or related to age.
Electrical Drainage	Transfer of Stray Current from a current source to another structure by means of a Bond.
Elevated Station	A Station constructed above ground level. The LRT Trackway leading to and from an Elevated Station is located on an elevated guideway or structure.
Enclosed Canopy	A Canopy where an integral part of the supporting wall structure is located on the outside of the Trackway, and the ends of the Station are open to allow the Trains to enter or exit the Platform area.
Engineer	The City of Edmonton's LRT Expansion and Renewal Branch.
Exclusive Use Corridor	A corridor where LRT is the only transportation mode, such as in tunnels, elevated guideways and any other corridors with no crossings or interfaces.
Executive Software	Product-specific software which is responsible for the safe operation of a VLC. The Executive Software safely evaluates Application Logic, manages communications and Vital input/output functions and performs self-diagnostics to ensure proper system safety. Executive Software is supplied by the VLC manufacturer and is not modified for site-specific application design.
Facility Network	The BMS communication network linking all BMS controllers within a facility, and is on the same network as the Main Network but sub-grouped for each facility.
Failsafe	A design feature or practice that in the event of a specific type of failure, inherently responds in a way that must cause no or minimal harm to other equipment, the environment, or to people.
Feeder Switch	An electrical switch (which is normally left closed) that connects the power distribution cables to overhead catenary wires.
Floating Ground	Grounding in a system that does not have direct connection to earth-ground. The track rails are considered a Floating Ground in the Traction Power System as they are designed to be isolated from ground.
Grade Separated	A cross-sectional form of Trackway located above or below the adjacent Transportation Corridor.

Human Factors Specialist	A specialist dealing with the application of information on physical and psychological characteristics to the design of devices and systems for human use.
Insulating Joint	A mechanical joint which electrically separates two adjacent structures or rails.
Integrated Hazard Analysis	An analysis that considers hazardous events or conditions that are caused by or controlled by multiple systems, elements or subsystems, as well as traffic, humans, or the environment.
Interlocking	An arrangement of Signals that allows the safe passage of one or more Trains through an arrangement of tracks while preventing conflicting movements.
Interlocking Signal	A Block Signal that governs Movement Authority through an Interlocking in addition to a Signal Block.
Kiss and Ride	A dedicated parking area near Stations or Transit Centres for short-term use by private vehicles to drop off or pick up Patrons. Long term parking is not permitted in Kiss and Ride areas.
Light Rail Vehicle (LRV)	A high floor, single, bi-directional rail vehicle used to carry Passengers on the LRT System.
Line of Sight	An operational constraint where the Train Operator is solely responsible for the safe movement of the Train.
Load Flow Study	A mathematical model that incorporates mechanical, electrical, and operational components of the LRT System to evaluate Traction Power system performance. It simulates the mechanical performance of the LRVs operating under various operational conditions to determine the necessary Traction Power equipment location, sizing, and ratings.
LRT Controller	A person in the LRT OCC responsible for the overall operation of the LRT System and its subsystems for delivery of revenue service and to manage the safety of Patrons, the public, and the Operator’s staff.
LRT Right-of-Way (ROW)	LRT operating area containing the track, systems, Stations and Wayside equipment.
LRT System	The City of Edmonton’s high floor LRT network.
Mainline	Track constructed for the purpose of carrying revenue Passengers.
Mixed-Use	The operating environment where the LRT alignment is integrated with vehicular, pedestrian, and cyclist traffic. There are no barriers or buffers providing separation from the Trackway. There are no Mixed-Use operations existing or planned on the LRT System.

Movement Authority	Operational permission for a Train to enter a designated area of the LRT Trackway.
Multi-Modal Station	A Station where transfer of Patrons from one mode of transportation to another such as bus transit, LRT or active modes occurs.
Non-Vital	Describes or refers to a system or subsystem, the function of which does not affect the safe operation of Trains. Non-Vital systems are not Safety Critical.
Office	Centralized Non-Vital systems for managing day to day LRT operations and maintenance activities at the LRT Operations Control Centre (OCC).
Open	The cross-sectional form of the Trackway where there are minimal restrictions on ROW width and the Trackway is not Grade Separated. Vertical restrictions are infrequent.
Operational Headway	Intended headway based on operational scheduling.
Operator	The City of Edmonton's Edmonton Transit Services Branch which both operates and maintains the LRT System.
Owner	The City of Edmonton.
Paratransit	A transportation service that supplements larger public transit systems by providing individualized rides without fixed routes or timetables
Park and Ride	A dedicated parking area for bus and LRT Patron's private vehicles. They are generally located adjacent to a Station or Transit Centre. Parking areas can be either At-Grade or in multi-level parkade structures.
Passenger	A Patron while in an LRV.
Patron	A user of the LRT System.
Patron Drop-off	A designated drop-off area for Patrons from private vehicles (Kiss and Ride), DATS vehicles, or taxi and ride share vehicles adjacent to Stations or a Transit Centres.
Platform	Portion of the Station directly adjacent to the Trackway where LRVs stop to load and unload Passengers.
Pocket Track	Track constructed for the propose of temporary storage, staging, and branching off the mainline track. Pocket track must be constructed to Mainline track standards.
Portable Operator Terminal	A laptop computer connected to the BMS at a controller

Project Development and Delivery Model (PDDM)	The City of Edmonton's framework for developing and delivering projects through all phases of a project life cycle, from strategic planning to project close-out for both growth and renewal infrastructure projects.
Protective Ground	Temporary ground Designed for the grounding of electrical conductors during temporary circuit isolations.
Rail Bond	A conductor ensuring the electrical continuity of rails at a joint for the purpose of traction power return.
RAM Program Plan	A document that outlines the set of time scheduled activities, resources, and events serving to implement the organization structure, responsibilities, procedures, activities, capabilities and resources that together ensure that an item with satisfy RAM requirements.
Refuge Zone	An area within the LRT ROW or an underground structure that provides a safe waiting area for ETS personnel during passage of Train. The Refuge Zone is defined by horizontal and vertical limits.
Return Circuit	All conductors which form the intended path for the traction power return current. The conductors may be running rails, return conductor rails, return conductors, and return cables.
Route Locking	Vital functionality ensuring that conflicting and opposing Train movements cannot occur within an Interlocking.
Sacrificial Anode	Metal, often zinc, which preferentially deteriorates when connected in a circuit to a metal structure.
Safety Certification	An element of the System Safety Program that documents the functional working of the System Safety Program and provides a documented database from which to validate the active processes necessary to produce a safe system that is ready for revenue service.
Safety Critical	Systems or devices whose failure could result in loss of life, significant property damage, or damage to the environment. These systems are generally designed to be Failsafe.
Safety Critical Software	Procedural computer code designed to provide a Safety Critical function. This type of software is typically associated with an engineered Design for a specific application. Due to the complexities of computer code control, safety systems engineering processes are typically required to evaluate the safety of this type of software system.
Semi-Exclusive Corridor	A corridor where the LRT ROW is located within a Transportation Corridor with physical barriers and/or separation from other transportation modes, limited crossing opportunities, and typically has a high speed of operation.

Service Vehicles	Vehicles used by the Operator's staff or its Contractors in the performance of maintenance and operational duties on the LRT System and related facilities.
Shared-Use Corridor	A corridor where the LRT ROW is located within a multi-modal Transportation Corridor, and may not have physical barriers and/or separation from other transportation modes, has frequent crossing opportunities, and typically has a range of operating speeds.
Shop Track	Pit tracks or embedded tracks constructed within the building limits of storage and maintenance facilities.
Signal	An LRT specific device at a fixed location consisting of signs and one or more lights of various colours and positions with the purpose of conveying information to an approaching Train.
Signal Aspect	The visual appearance of a fixed Signal which conveys operational information.
Signal Block	A discrete section of railway track that is bounded by Block Signals.
Signal Indication	The meaning of a Signal Aspect, which conveys Movement Authority and related information to the Train Operator.
Signal System	An integrated system of Wayside and off-corridor hardware and software that uses Signals to control the safe movement of Trains on the LRT System and is managed through the LRT Operations Control Centre.
Speed Check	A device capable of stopping an LRV which is travelling faster than authorized at a discrete point and direction.
Station	A facility where LRVs stop to pick up or drop off Passengers. Stations primarily consist of a Platform area for Passenger loading/unloading, fare equipment, and information on Train arrivals and departures. Other related components may include service areas, stairs, ramps, escalators, elevators, advertising, and Patron amenities. Stations can be fully enclosed, partially covered with simple roof design or fully open. They can be located underground, elevated, or At-Grade, and can be within exclusive use, semi-exclusive use or shared use ROWs.
Stray Current	The small amount of current that flows through paths other than the intended main traction power system circuit.
Stray Current Mitigation Plan	A document that establishes Stray Current control requirements, identifies the infrastructure to be considered in the Stray Current design, and provides verification and validation requirements for the design.

Stray Current Survey	Measurements and calculations to determine the effect of a project on Stray Current levels.
Street	The area within the Transportation Corridor that does not include the LRT ROW and is reserved for other modes of transportation such as pedestrians, cyclists, and vehicular traffic.
Structural Clearances	The minimum horizontal and vertical clearance requirements for Trackway elements.
Superelevation Effects	The vehicle lean induced by a specific difference in elevation between two rails of a track. This effect is considered independently of other effects on the dynamic envelope.
Sustainable Urban Integration	The process of designing livable, pedestrian-friendly environments and adding enhancements that reflect the feel and character of each of the neighbourhoods along the LRT ROW.
Switch Locking	Vital functionality which prevents moveable special trackwork such as switch points from changing position while a Train occupies the trackwork or has Movement Authority to travel over the trackwork.
Systems Assurance	A planned and systematic set of engineering activities necessary to assure the achievement of specified Reliability, Availability, Maintainability, and Safety (RAMS) goals.
System Assurance Audits	A systematic and independent examination to determine whether the procedures specific to the Systems Assurance requirements of a product comply with the planned arrangements, are implemented effectively, and are suitable to achieve the specified objectives.
Tie Switch	An electrical switch, which is normally left open, that connects two adjacent traction power circuits.
Time Locking	Vital functionality which prevents Route Locking from releasing for a period of time after an Interlocking Signal is placed back to its most restrictive aspect.
Trackway	The fixed physical components that directly support and guide an LRV, including all the trackwork components and the supporting structure upon which the track rests.
Trackwork Installation and Maintenance Tolerance	The allowable deviation of the installed track from the design track centreline and the allowable tolerance for maintenance.
Traction Power Substation	The facility at which the medium voltage alternating current from a utility provider's primary supply system is transformed and rectified to the low voltage direct current power for LRVs.

Traffic Locking	Vital functionality which prevents the simultaneous Movement Authority of Trains in opposing direction within a Control Block.
Train	Any rail borne equipment capable of operating under its own power.
Train Operator	The person who is in control of a Train.
Transit Centre	A transfer facility and associated amenities for buses and other types of transit service. Patrons using one type of transit service can transfer to another.
Transportation Corridor	The overall ROW that includes the LRT ROW, the Urban Interface, and areas for all other modes of transportation. The extents of a Transportation Corridor are typically defined by legal property limits.
Unidirectional (Drainage) Bond	A Bond that will only permit current flow in one direction. This may be achieved using active devices such as relays or passive devices such as diodes.
Universal Design	A series of principles for design that consider the varied abilities of users. The principles are: equitable use, flexible use, intuitive use, perceptible information, tolerance for error, low physical effort, and space for approach and use.
Urban Corridor	A Transportation Corridor which has a heightened degree of interaction between the LRT and other transportation modes and surrounding land uses, with limited barriers and a slow Train operating speed.
Urban Interface	The confluence of the LRT ROW (including Stations), with the Street environment and other adjacent land uses where the integration of LRT infrastructure with adjacent uses can occur.
Urban Style	A design philosophy that integrates the LRT System into the local context with smaller Stations that have enhanced Accessibility connecting active transportation modes. Key components include a slow Train operating speed, visually open Trackway, and a focus on active mode integration.
Utility Complex	A facility, configured as a typical and expandable building form, that houses various LRT systems rooms including those for Traction Power Substations, Signals, communications, electrical distribution, mechanical, and others as required.
Variable Frequency Drive	A device which changes the rotational speed of the motor of a piece of rotational equipment.

Vital	Describes or refers to a system or subsystem, the function of which directly affects the safe operation of Trains. Vital equipment and systems are Designed under Safety Critical Engineering processes.
Vital Logic Controller	A highly reliable and failsafe programmable logic controller and associated Vital input/output interfaces which is designed explicitly for railway signaling applications.
Voltage-Limiting Device	A protective device whose function is to prevent existence of high touch potential.
Wayside	Areas along the Trackway where LRT related systems and equipment may be placed.
Yard Track	Track that does not carry revenue Passengers and is used for Train storage and maintenance. Yard Track is designated by a Yard Limit sign.

CHAPTER 20
References

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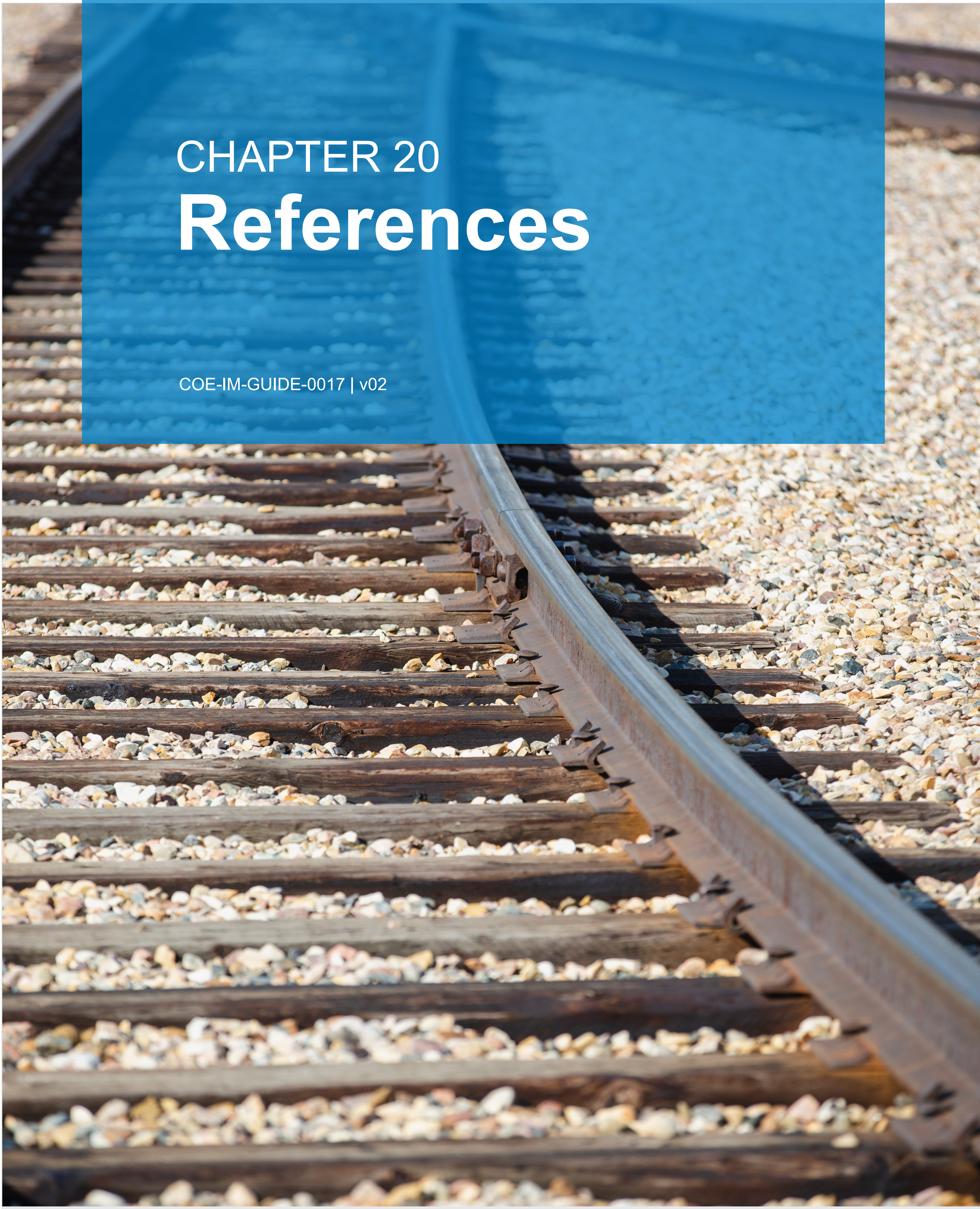

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