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.

Attachment
Urban LRT Leadership Charter

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.

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Integrated Infrastructure Services

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1.0 GENERAL

1.1 INTRODUCTION

1.1.1 Purpose
These guidelines provide criteria and information for City of Edmonton staff, Designers, and Contractors, and establish a uniform basis for the Design of Light Rail Transit (LRT) projects for the City of Edmonton’s high floor LRT network, consisting of the Capital Line and Metro Line.

This chapter provides overarching information that impacts multiple aspects of the 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.

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 that must be incorporated into 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.

Although every effort has been made to include all applicable codes and standards in each chapter of these guidelines, 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 are to comply with in the Design.

If there is a variance between requirements stated in these guidelines and the other documents referred to herein, the Designer should seek direction from the Engineer regarding which requirement must be complied with and incorporated in the Design. See Section 1.3.1 for more information.

Design and construction of LRT buildings and systems must comply with all current municipal, provincial, and federal codes and standards where applicable. Where expressed 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 assess the recommendation and provide direction.

If warranted, the Designer must consult with the Authority Having Jurisdiction (AHJ), as they are a safety codes officer in the buildings discipline exercising authority in accordance with Section 28 of the Safety Codes Act. For all other non-safety matters, the AHJ will be the Engineer. The AHJ will be further defined in the Contract Documents.
CITY OF EDMONTON – LRT DESIGN GUIDELINES

The LRT Systems Assurance guidelines provide details on the system assurance process and requirements, including safety certification, and identify 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 are to be made in accordance with the Design Guideline Variance Request procedure set forth in Section 1.3.1.

Some of the documents listed below, and throughout these guidelines, may not be publicly available. These documents may be requested from the Engineer or the Owner.

1.1.4.1 Acts, Codes and Regulations
- CSA S6 – Canadian Highway Bridge Design Code [3]

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 C458C [9]
- Sustainable Building Policy C532 - Leadership in Energy and Environmental Design (LEED Silver) [10]
- Zoning Bylaw 12800 [11]

1.1.4.3 Reference Standards
- Edmonton Design and Construction Standards [12]
- Edmonton Roadway and Walkway Lighting Design Standards [13]
- 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]
- High Floor LRT Sustainable Urban Integration Guidelines
- High Floor LRV Specifications
- Long-Term High Floor LRT Signaling & Train Control Strategy
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 requirement
- Should – denotes a recommended, but non-mandatory requirement
- May – denotes an optional requirement

1.2 SYSTEM DESCRIPTION
The LRT System primarily 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, side-loading and staggered Platforms. 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 LRT
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 Designer must refer to the City of Edmonton’s High Floor LRT SUI Guidelines for detailed information. An Urban Style LRT Design must adhere to the following key principles:

- Infrastructure scale – building smaller scale Stations that are spaced at 800-1000 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
1.2.2 **LRT 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 events: 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 twice as 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 and system safety and security. The Transportation Corridor type also influences the degree of SUI to be applied. Exclusive Use Corridors are limited to areas such as LRT-only tunnels and elevated guideways and the majority of the LRT System is 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 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 is permitted

Table 1.1 Transportation Corridor and Operations Matrix presents requirements and parameters associated with differing 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 (that operating scenario is not contemplated in Table 1.1).
### Table 1.1 Transportation Corridor & Operations Matrix

| Corridor Type | Traditional Signaling | Traditional Signaling | Traditional Signaling | Modified traffic/ | Modified traffic/ |
|---------------|-----------------------|-----------------------|-----------------------| train signaling   | 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**
- operating cost per kilometer times base cost*: 1, 1.5, 2, 1.5, 2

#### 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

**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**
- operating cost per kilometer 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, NA, 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**
- operating cost per kilometer times base cost*: 1, 1.5, 2-3 **, 1.5, 2-3 **

### Notes:
- **Base**: the operating cost per kilometer with an operating speed of 70 kp/h
- **2 - 3 Base**: cost premium is dependent on the actual operating speed (≤30kp/h)
1.3 DESIGN CONSIDERATIONS

The 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.

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 1-A. 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
- The Advisory Board for Persons with Disabilities
- Edmonton Transit System Advisory Board
- The Edmonton Design Committee
- The Edmonton Arts Council

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

Legend

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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 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 its 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.

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

Design life is the length of time that the Designer must use when designing a component of the LRT System. Design should generally be conservative and use materials and products especially suited for heavy, prolonged usage. In the application of materials and products, the Designer should strive for minimal maintenance requirements and recommend maintenance procedures that are as convenient as possible to carry out.

The Designer must use a design life, or product life expectancy in which the given component is expected to perform within its specified parameters 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 catenary bases and poles – 50 years
- Traction Power Substation (TPSS) equipment – 40 years
- All other electrical systems – 35 years

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.


1.3.5 Accessibility
1.3.5.1 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. In adopting an Urban Style LRT philosophy and SUI principles, there is 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 guidelines to satisfy the AHJ pursuant to the Safety Codes Act [1]. 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.

1.3.5.2 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 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 feasible 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 Accessibility Advisory Committee (AAC), Edmonton City Council has also established the Edmonton Transit System Advisory Board and the Disabled Adult Transit Service (DATS) Working Group. Both are available for review of Accessibility design issues as required.

1.3.6 Sustainability

Portions of the Design may be subject to the City’s Sustainable Building Policy C532 - Leadership in Energy and Environmental Design (LEED Silver) [10]. Before beginning the Design, the Designer will confirm with the Engineer which aspects of the Design are subject to Policy C532 and complete the Design accordingly.
1.3.7 Human Factors
In addition to the requirements in Section 1.3.5, Accessibility, all interfaces, spaces, and systems that interact with Patrons, Passengers, Transit Operators (TO), and maintainers must be reviewed by a Human Factors Specialist. A human factors assessment will apply theory, principles, data, and methods of design in order to optimize safety, product design, human capability, human well-being, human-machine interface, maintainability, and overall system performance. The human factors assessment will be based on allowing usage by Patrons, Passengers, TO, and maintainers within the fifth percentile female to ninety-fifth percentile male adult body type ranges.

1.3.8 Maintenance
Each chapter within these guidelines provides 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 resulting Design requirements.

1.3.9 Service Integration
The LRT System must be designed as an integral part of the City’s overall multi-modal transportation network. Design considerations must be made for efficient interchange of Patrons to and from other transportation modes.

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

1.3.11 Proven Hardware
The Design must use proven subsystems, hardware, and design concepts. All subsystems and components, such as vehicles, signaling, communications, 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 outlined in Section 1.3.1 must be followed when requesting a waiver.

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

1.3.12 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.
1.3.13 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 project management and project delivery best practices.

1.3.14 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 auditable record of safety measures for the LRT project.

Where practical, and considering the size and complexity of the system, Designers should 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 should be agreed upon with the Engineer. Refer to the City’s LRT Systems Assurance Guideline for further details.

1.3.15 Safety and Security
Further to Section 1.3.14, the safety and security of Patrons, Passengers, TO, 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.

1.3.16 Flexibility
The Design must accommodate extensions, facility upgrades, equipment, and any other infrastructure that is expected. 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 any planned future equipment
- The provision of electrical load capacity for any additional planned loads

1.3.17 Facility Development Review
All LRT facilities and buildings that can 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 phase. 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 contract award.

1.3.18 Land-Use
The Designer must review any available and applicable land-use planning documents to ensure the Design reflects 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.

1.3.19 Local Climate 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 confirm the actual range of conditions at the time of Design through Environment Canada (Environment and Natural Resources Canada).

- Temperature Range: -40°C to +40°C
- Average Altitude: 670 m above sea level
- Humidity Range: 0% to 100%
- Sustained Wind Speed: 70 km/h
- Wind Gusts: 120 km/h
1.3.19.1 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 0°C.

1.3.19.2 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.

1.3.20 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 adequate detail to identify approximate horizontal and vertical track alignments, Station locations, configurations and type, surrounding roadway geometry, major structure locations, utility complex locations and footprints, and any other elements needed to determine the project’s land acquisition needs. The Concept Plan must be validated with a desk-top review of 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 supported by transportation micro-simulation modelling. TPSS 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, consider integration with surrounding land uses, and undertake 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 Contractor must have the shop drawings 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.

**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.

### 1.4.2 Standard Record Documents
The Contract Documents will provide direction to the Designer regarding 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 LRT Standard Record Documents Guidelines. They generally comprise the following and will be specified in the Contract Documents:

- Record drawings
- As-built drawings
- Operation and maintenance manuals (O&M)
- Shop drawings
- Guarantees or warranties
- Project closeout records and reports

### 1.4.3 Operation and Maintenance Manuals
The Contractor is responsible for providing 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 of Edmonton’s LRT Operation & Maintenance Manual Guidelines, which the Designer must include or refer to in the Contract Documents.

1.4.4 Contractor Requests for Information and Non-Conformance Reporting
The Designer must respond to and address any Requests for Information (RFI), related to the Design that have been submitted by the Contractor through the project’s duration. The Designer must also report on the acceptability of any technical aspects of Non-Conformance Reporting (NCR) that occur 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 will 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 [27] 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.
<table>
<thead>
<tr>
<th>Date:</th>
<th>Design Change Number: LRTDG_###</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project:</td>
<td>Relevant Design Guideline: LRT Design Guidelines</td>
</tr>
<tr>
<td>City Project Manager:</td>
<td></td>
</tr>
</tbody>
</table>

**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:**

<table>
<thead>
<tr>
<th>Consultant PM Name</th>
<th>Date</th>
<th>Approved:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consulting Firm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Director Name**

Director, LRT Infrastructure Delivery

**Consultant Design/Deputy PM Name**

<table>
<thead>
<tr>
<th>Date</th>
<th>Project Manager Name</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consulting Firm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Project Manager Name**

Project Manager
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Vehicles
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2.0 VEHICLES

2.1 INTRODUCTION

This chapter presents general requirements, guidelines, and criteria for designing high floor Light Rail Vehicles (LRVs) 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 high volume of pedestrian, cyclist, and motor vehicle interactions.

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 2.7 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 [1]. The dynamic braking system must provide full 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 to maximize energy savings.

Friction brake equipment must comply with EN 13452 [1].

Electromagnetic track brakes that apply directly to the rail surface must be provided on all bogies in accordance with EN 13452 [1].

2.2.4 Bogie

LRV bogies must meet the following specifications:

- Bogie axle centre of 1.8 m
• Wheel diameter limits of:
  \[
  \begin{align*}
  &\text{720 mm } \pm\text{ 0.5 mm for new wheels} \\
  &\text{660 mm minimum for worn wheels}
  \end{align*}
  \]

2.2.5 Pantograph
The LRV pantograph must comply with EN 50206-2 [2] or IEC 60494-2 [3] 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 outlined in the latest version of ETS-LRV-GTI-0002 [4].

The U2 vehicles (1978-1983) were designed to German standards including Verband Deutscher Electrotechniker (VDE), BOSTrab [5] 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 [4].

2.2.7 Environmental Considerations
LRVs and their subsystems must be designed for, and provide full functionality, during operation in the environmental conditions as defined 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 [6].

2.2.8.1 Wheelchair Spaces
At least two Passenger doors on each side of the LRV must be designed for wheelchair compatible access and must not be less than 1250 mm in width. Wheelchair spaces and access doors should be positioned to ensure 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 coupler design 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.

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

Table 2.1 Loading Summary

<table>
<thead>
<tr>
<th>Loading</th>
<th>Passenger Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>AW0</td>
<td>Empty</td>
</tr>
<tr>
<td>AW1</td>
<td>Fully seated load + train operator</td>
</tr>
<tr>
<td>AW2</td>
<td>Fully seated load + train operator + 4 standees/m²</td>
</tr>
<tr>
<td>AW3</td>
<td>Fully seated load + train operator + 6 standees/m²</td>
</tr>
<tr>
<td>AW4</td>
<td>Fully seated load + train operator + 8 standees/m²</td>
</tr>
</tbody>
</table>
2.2.13 Crash Energy Management
The crash energy of the LRV must comply with EN 15227 category C-III [7], 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 forms and alignment. Under-run protection is to be provided without damaging the LRV or Trackway, and without interfering 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 [8]. 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 the each LRV must be evaluated according to EN 12299 [9] 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, and all normal vehicle acceleration, braking, and its speed conditions.

All LRVs must comply with ISO 2631 [10] for mechanical vibration and shock.

2.2.18 Noise
The method of measurement for internal noise levels within the TO’s cab and the Passenger compartment must comply with the procedure described in ISO 3381 [11]. Internal noise levels within the TO’s cab must not exceed values stated in Table 2.2.

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

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

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

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 [12].

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 operater 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 a number of pieces of 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.
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3.0  CLEARANCES AND RIGHT-OF-WAY

3.1  INTRODUCTION

This chapter provides criteria for clearances and Right-of-Way (ROW) and sets out the acceptable dimensions required to assure that proper clearances are provided 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 LRT ROW limits.

3.1.1  Applicable Codes, Standards, and Regulations

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

- Manual for Railway Engineering [1]
- Track Design Handbook for Light Rail Transit [2]

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 possible dimensions taken from the Light Rail Vehicles (LRV)s 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 loads and load configuration is discussed 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 outlined above.

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
• 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 conform to the DVDE. The Designer must consider the clearance requirements to Wayside equipment at Platforms and around other structures and installations that may 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:

\[
VRCE = DVDE + SE + CE + TT + SC \quad (Appendix\ 3A)
\]

Where,  
VRCE = Vehicle Running Clearance Envelope  
DVDE = Design Vehicle Dynamic Envelope  
SE = Superelevation Effect  
CE = Curvature Effect  
TT = Trackwork Installation and Maintenance 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 using the formula as follows:

For in-swing:

\[
\Delta_i = R (1 - \cos \theta) \quad (Appendix\ 3A\ Figure\ 3.2)
\]

For out-swing:

\[
\Delta_o = \left( (R - \Delta_i + W/2)^2 + A^2 \right)^{1/2} - R - W/2 \quad (Appendix\ 3A\ Figure\ 3.2)
\]

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  
\( \Delta_i \) = in-swing clearance in mm  
\( \Delta_o \) = out-swing clearance in mm

Appendix 3-B shows the calculated values for a curve radius \( R = 180 \) m for the design vehicle and rail borne LRT maintenance vehicles.
Out-swing is based on a worst-case scenario by 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-C illustrates the Superelevation Effect conditions and provides a formula for calculating the displacement.

### 3.2.2.3 Trackwork Installation and Maintenance Tolerances

The following are the tolerance limits for these conditions:

- 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 are to be 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 Walkway or Catwalk
- Minimum running clearance of 150 mm along elevated Trackway parapet, wall, and all 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 Figures 3.4 and 3.5.
Where balance weights are located between tracks, the OCS poles must be offset to ensure that the weights are 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 hard or soft 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 conditions presented 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 facilities to be constructed or modified.

### 3.3.3 Platform Clearances

Accessibility requirements define the minimum horizontal and vertical gap distance between the Platform edge and the LRV static envelope. Refer to Appendix 3A Figure 3.6. 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 Platform end wall or any obstruction on and above the Platform level must be 1700 mm.

**Vertical clearances:**

- The elevation at the edge of Platform finished surface above TOR must not exceed 890 +5/-15 mm.

### 3.3.4 Tunnels

Clearance requirements differ based on the tunneling methodology used.

On curved track with superelevation, a bored 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 Figures 3.7 and 3.8.

The concrete duct bank (under the Catwalk) is considered a permanent structure.

### 3.3.5 Box Structure

A typical single box structure is illustrated in Appendix 3A Figure 3.9.

### 3.3.6 Overpass/Bridge Structure

A typical elevated structure is illustrated in Appendix 3A Figure 3.10.
3.3.7 Retaining Structure
A typical cross-section for retained cut and fill section is illustrated in Appendix 3A Figures 3.11 and 3.12 respectively.

3.3.8 Special Clearance Situation

3.3.8.1 Under-Car Clearances
The maximum allowable intrusion of Signals and trackwork equipment mounted on ties or track slab along the Trackway must be 50 mm above the TOR.

3.3.8.2 Equipment and Pedestrian Safety
A minimum clearance must be provided between the catenary 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 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 required width of a Transportation Corridor.

3.4.1 LRT Elements and Components
Basic requirements to be included in segments of level tangent track 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
- Pedestrian swing gates
- Platform configurations
- LRT related utilities
- LRV storage tracks
- Building structures required for Station access and standalone Traction Power Substations (TPSS) or Utility Complexes
- LRT related landscaping
- Shared use paths and related landscaping
- LRT Operational 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 are shown for the various track types in Appendix 3A Figures 3.13 to 3.20.
APPENDIX 3A – FIGURES
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FIGURE 3.2
CURVATURE EFFECTS
DESIGN VEHICLE.

<table>
<thead>
<tr>
<th>VEHICLE/EQUIPMENT</th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>C (mm)</th>
<th>W/2 (mm)</th>
<th>R (mm)</th>
<th>INSWING Δ₁ (mm)</th>
<th>OUTSWING Δ₁₂ (mm)</th>
<th>INSWING CLEARANCE (mm)</th>
<th>OUTSWING CLEARANCE (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESIGN VEHICLE</td>
<td>7942</td>
<td>4082</td>
<td>3880</td>
<td>1730</td>
<td>180</td>
<td>41</td>
<td>132</td>
<td>1771</td>
<td>1862</td>
</tr>
</tbody>
</table>

FORMULAE:

*INSWING CALCULATION

Δ₁ = R (1 - Cos θ)

**OUTSWING CALCULATION

Δ₁₂ = (((R + W/2)² + A²)² - 1/2) - R - W/2

WHERE:

θ = Sin⁻¹ (C / R)

A = B + C, EXTREME END OF VEHICLE/EQUIPMENT

B = MID DISTANCE BETWEEN WHEEL BASE

R = VEHICLE OVERHANG FROM WHEEL BASE

C = FRONT END OR REAR END OF VEHICLE

W = HALF THE DISTANCE BETWEEN WHEEL BASE

A = DYNAMIC WIDTH OF VEHICLE/EQUIPMENT

R = RADIUS OF CURVE (IN M)

Δ₁ = INSWING CLEARANCE

Δ₁₂ = OUTSIDE CLEARANCE

Date

Revision
Formulae:

\[ v = 0.5 \times E \]
\[ h = \frac{a - v}{b} \times E \]

\[ c = \frac{1}{2} \times \text{LRV Dynamic Envelope} + \text{Effect of Inswing/Outswing} + \text{Effect of Super-elevation} + \text{Structural Clearance to Catwalk} \]

Where:

- \( E \) = Super-elevation of Track
- \( a \) = Height of Vehicle above rail at the vertically shifted center of tunnel
- \( b \) = Track center to center distance
- \( v \) = Vertical shift of tunnel centerline relative to track centerline
- \( h \) = Horizontal shift of tunnel centerline relative to track centerline
- \( c \) = 1/2 clearance to top of catwalk from track centerline
- \( 1/2 \text{ LRV Dynamic Envelope} = (v/2 = 1458) \text{ at floor level} \)

Catwalk Topping Inswing/Outswing to be determined in accordance with 1/2 LRV Dynamic Envelope (v/2 = 1458) at floor level.

Figure 3.3
Super-elevation effects on curves

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision</th>
</tr>
</thead>
</table>

Chapter 3
Clearances and ROW
NOTES:
* Width is a typical dimension on tangent, it may be reduced on curved track due to curvature effects.
FIGURE 3.5
CLEARANCE ENVELOPE LEVEL TANGENT EMBEDDED TRACK (SHARED USE)
**NOTES:**
* The absolute minimum dimension is based on tangent track with no super-elevation.

**FIGURE 3.8**
CLEARANCE ENVELOPE
LEVEL TANGENT TRACK
(SEM TUNNEL)
FIGURE 3.10
CLEARANCE ENVELOPE
LEVEL TANGENT TRACK
(ELEVATED STRUCTURE)
FIGURE 3.11
CLEARANCE ENVELOPE
LEVEL TANGENT TRACK
(RETAINED CUT)

NOTE:
LRT ROW LIMIT WILL BE DEPENDENT ON TOPOGRAPHY
AND RETAINING WALL FOOTING DESIGN.
FIGURE 3.12
CLEARANCE ENVELOPE
LEVEL TANGENT TRACK
(RETAINED FILL)

NOTE:
LRT ROW LIMIT WILL DEPEND ON
TOPOGRAPHY AND RETAINING WALL
FOOTING DESIGN.
NOTES:
1. CONTACT WIRE WILL BE ON BOTH SIDES OF CENTRELNE AT ANY GIVEN ALIGNMENT.
2. ONLY ONE FEEDER IS REQUIRED AND MAY BE LOCATED ON EITHER SIDE ON TANGENT TRACK.
   - MUST BE ON OUTSIDE IN CURVES.

FIGURE 3.13
VERTICAL CLEARANCE TO OVERHEAD CATEenary
FIGURE 3.14
VERTICAL CLEARANCE TO UTILITIES CROSSING OVERHEAD CATenary

NOTES:
- DUCTS, CONDUITS, AND PIPES SHOULD CROSS THE TRACK AT RIGHT ANGLES TO MINIMIZE INTERFERENCE. BOTTOM OF DUCT, CONDUIT, OR PIPE MUST BE 500 mm ABOVE CONTACT WIRE.
SECTION 3.24

ROW DESIGN ELEMENTS NOT SHOWN

NOTE
1. THE MINIMUM DIMENSION IS BASED ON TANGENT TRACK WITH NO SUPERELEVATION.
2. DIMENSIONS SHOWN (THUS) UNDER UTILITY ARE TYPICAL AND ARE MEASURED FROM TOP TO THE UNEVEN SIDE OF THE UTILITY DEVICE.

FIGURE 3.16
TYPICAL SECTION COMBINED MAJOR TRACKWAY ELEMENTS TBM TUNNEL

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Track Alignment
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4.0 TRACK ALIGNMENT

4.1 INTRODUCTION

This chapter defines requirements for the geometric design of track alignment for the 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 acceptance is obtained from 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 [1]
- Track Design Handbook for Light Rail Transit [2]

4.1.2 Design Basis

The Design must consider the design vehicle, overall LRT operations, and maintenance considerations. Specifically, 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 possibility of a negative superelevation condition

4.1.4 Design Speed

All track should be designed for the maximum design speed dictated by geometric and operational constraints of the section under consideration. For each vehicle, the following maximum design speeds apply:
• 80 km/h for LRV on Mainline;
• 30 km/h for work Train on Mainline; and
• 10 km/h for Yard Track except for vehicle testing track where the maximum design speed will be 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 Reference Lines
The reference line for alignment design will be the track centreline. A separate chainage will be run along the centreline of each track. All dimensions and clearances pertaining to the track must be referred to the centreline. The reference track centreline must be tied to the established Survey Control Network (SCN).

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

4.2.3 Tangent Sections

4.2.3.1 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 2 seconds.

4.2.3.2 Tangent Lengths Between Curves in the Same Direction
For curves oriented in the same direction, a compound curve or compound spiral is preferred over a short tangent length between curves. If a tangent section is required, the minimum tangent length requirement for reverse curves applies.

4.2.3.3 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.

4.2.3.4 Tangent at Special Trackwork
All special trackwork must be located on tangent track.

For ballasted 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 entail a reverse curve movement, 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.

4.2.4 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 is 180 m.

The minimum circular curve radius for Yard Track is 35 m.

The following must be analyzed when any deviation from this standard 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 to be provided must be the greatest of the computed value from equations (1), (2), and (3) as follows:

a. 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:

$$L_s = \frac{E_a \times V}{108}$$  \hspace{1cm} (1)

Where, $V =$ maximum speed in km/h.

b. 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:

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

And:

$$L_s = \frac{E_u \times V}{180}$$  \hspace{1cm} (2)

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

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

\[ L_s = \frac{(E_1 - E_2) \times V}{108} \times 2 \]  
\[ L_s = \frac{(E_u_1 - E_u_2) \times V}{108} \times 2 \]  
\[ L_s = 15 \]  

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  
- \( E_u_1 \) = the larger unbalanced superelevation in the two curves in mm  
- \( E_u_2 \) = 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 is 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
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 is 30 mm/s for the maximum speed of Train operating on the curve.

**Actual Superelevation ($E_a$)**
The maximum actual superelevation ($E_a$) permitted is 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 can be determined as follows:

\[
F_c = \frac{w \times V^2}{g \times R}
\]

Where, $F_c =$ centrifugal force acting radially outward, in newtons  
$w =$ 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,

\[
\frac{F_c}{E_e} = \frac{w}{B}
\]

Where, $F_c =$ centrifugal force acting radially outward, in newtons  
$E_e =$ 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,
Balance Speed ($V_b$)
The balanced speed is determined by substituting $E_a$ equal to 100 mm as follows:

$$V_b = \sqrt{\frac{E_a \times R}{11.83}}$$  \hspace{1cm} (8)

Where,
- $V_b = \text{balanced speed in km/h}$
- $E_a = \text{actual superelevation in mm}$
- $R = \text{radius of circular curve in m}$

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 is permitted in determining an optimal range of safe operating speed for the alignment under consideration. The maximum allowable unbalanced speed is determined by substituting $E_a$ equal to 100 mm in equation 9:

$$V_u = \sqrt{\frac{(E_a + E_u) \times R}{11.83}}$$  \hspace{1cm} (9)

Where,
- $V_u = \text{unbalanced speed in km/h}$
- $E_a = \text{actual superelevation in mm}$
- $E_u = \text{unbalanced superelevation in mm}$
- $R = \text{radius of circular curve in m}$

Alternatively, the optimal range of actual superelevation satisfying the lateral acceleration criteria can be determined in equation 10:

$$Z = 11.83 \times \frac{V_u^2}{R} - E_a$$  \hspace{1cm} (10)

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

4.2.3.6 Superelevation Constraints in Turnouts
For ballasted 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 roadways, the gradient may be dependent on the roadway profile to minimize elevation differential between the road and the track. For safety and comfort, vertical alignment at track and road intersections must be designed to provide smooth crossing of both LRVs and roadway vehicles.

4.3.1 Reference Lines
Gradients must be referred 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:

<table>
<thead>
<tr>
<th>Track Segment</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline</td>
<td>4.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Stations*</td>
<td>1.0%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Storage and Yard</td>
<td>0.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Shop</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

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

4.3.3 Vertical Tangent
The minimum length of tangent grade between vertical curves must be 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:

<table>
<thead>
<tr>
<th>Design Basis</th>
<th>Length of vertical curve (LVC)</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum length permitted</td>
<td>60 m</td>
<td>(11)</td>
</tr>
<tr>
<td>Rate of change in grade</td>
<td>$LVC = A \times K$</td>
<td>(12)</td>
</tr>
<tr>
<td>Vertical acceleration</td>
<td>Crest curves $LVC = 0.0047AV^2$</td>
<td>(13a)</td>
</tr>
<tr>
<td></td>
<td>Sag curves $LVC = 0.0025AV^2$</td>
<td>(13b)</td>
</tr>
</tbody>
</table>

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 is 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
For ballasted 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.
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5.0 TRACKWORK

5.1 INTRODUCTION

This chapter presents the general requirements, guidelines, and criteria for the design of track and trackwork components for the LRT System. Aspects of track and related track components are discussed including rail, special trackwork, support structures, fastening devices, and related hardware.

Technology and products used 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. This technology must be compatible with the Operator’s existing technology.

These guidelines form the basis of the trackwork design and the framework for evaluating alternative systems. Any variance from these guidelines requires the Engineer’s approval.

5.1.1 General Standards and System Requirements

The trackwork design must provide the LRT System with continued acceptable performance, ease of O&M, 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 component must be submitted to the Engineer for acceptance, along with consultation from 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 as follows:

- American Railway Engineering and Maintenance Association (AREMA)
- American Society for Testing and Materials (ASTM)
- Canadian Standards Association (CSA)
- Transportation Cooperative Research Program (TCRP)
Consideration must be given to the design vehicle size, load, performance, and dynamic clearances as described in Chapter 2, Vehicles and Chapter 3, Clearances and Right-of-Way.

5.1.3.1 Design Speed and Design Wheel Load
All tracks must be designed for the maximum design operating speeds dictated by the geometric and operational constraints:

- The maximum design speed for Light Rail Vehicle (LRVs) on Mainline track is 80 km/h
- The maximum design speed for auxiliary equipment on Mainline track is 30 km/h
- The maximum design speed for LRVs on Yard Track is 10 km/h
- The maximum design wheel load of an LRV is 5800 kg
- The maximum design wheel load of the 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 defined 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 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 follows:

Direct Fixation Fasteners
Lateral adjustment of ±15 mm in increments of 3 mm must be provided. Vertical adjustment from 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 to the direct fixation track structure.

Concrete Crossties
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 5.3.5 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 a minimum 3 m ahead of the point of switch. This transition can 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 5.21 and Figure 5.22) 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 rail-mounted maintenance equipment requirements and pedestrian 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 flangeway depth must accommodate dirt and debris without causing wheel lift.

The following are the flangeway requirements for the standard Association of American Railroads (AAR) wheel profile used 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)
- Guard 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. All trackwork systems in direct contact with the LRV must have provision for electrical isolation from the 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 is 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 facilities.
The grounding system and insulating requirements must be designed and constructed based on a grounding study as described 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 to minimize the impact of noise and vibration
- 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 presented in Chapter 14, Urban Integration.

5.2 TRACK STRUCTURE
Mainline Track should be:

- Concrete tie and ballast in At-Grade areas protected with hard barriers
- Direct fixation, typically on concrete plinths, in Grade Separated areas
- Embedded in Urban Corridors at lower operating speeds

Mainline special trackwork may be installed as a ballasted track on concrete tie, direct fixation on track slab with elastomeric grout pads, or direct fixation on concrete plinths.

Yard Track should use timber ties, screw spike, and ballast construction.

Alternative track structures will not be considered without a proven revenue service record of at least two years on an LRT System 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 the 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 should conform to the following AREMA [1] recommendations:

- Concrete tie – bearing pressure at the ballast/tie interface should not exceed 585 kPa (85 psi)
- Composite tie – bearing pressure at the ballast/tie interface should not exceed 448 kPa (65 psi)
- Wood tie – bearing pressure at the ballast/tie interface should not exceed 448 kPa (65 psi)
- Bearing pressure at the subgrade/sub-ballast interface should not exceed 138 kPa (20 psi)

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 of direct fixation fasteners on concrete structures 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
Wood tie and ballast track, as shown in Appendix 5A Figure 5.2, should be used for Yard Track.

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

Refer to Section 5.2.1.1 for the spacing of wood ties.

5.2.2.2 Composite Tie and Ballast Track
Composite tie and ballast track, as shown in Appendix 5A Figure 5.1, should be used for At-Grade crossings and track transitions on Mainline track.

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

Refer to Section 5.2.1.1 for the spacing of composite ties.

5.2.2.3 Concrete Tie and Ballast Track
Concrete tie and ballast track, as shown in Appendix 5A Figure 5.1, should be used for At-Grade Mainline track construction.

The rail fastening system for precast concrete ties should 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 5.2.1.1 for the spacing of concrete ties.

5.2.2.4 Concrete Tie and Ballast Track on Concrete Slab
Concrete tie and ballast track on concrete slab, as shown in Appendix 5A Figures 5.3 and 5.4, should be used in areas where there are depth restrictions preventing construction of a full granular track bed.

The minimum ballast depth under the tie is 225 mm.
The rail fastening system for precast concrete ties should consist of cast-in-place cast iron shoulders, spring clips, rail pads, and insulators for fastening 115 lb RE rail.

Refer to Section 5.2.1.1 for the spacing of concrete ties.

**5.2.2.5 Direct Fixation on Concrete Slab**

Direct fixation track on concrete slab should be used in portal transitions and in tunnels, as shown in Appendix 5A Figures 5.5 to 5.7.

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

**5.2.2.6 Direct Fixation on Concrete Slab with Restraining Rail**

Direct fixation track on concrete slab with restraining rail, as shown in Appendix 5A Figures 5.8, should be used on aerial structures.

Restraining rail must be installed on the gauge side of both rails for the purpose of restricting the travel distance of a derailed vehicle.

Refer to Section 5.5.2 for concrete plinth and insert requirements.

**5.2.2.7 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 track should use 115 lb RE rail.

Embedded track structures should be constructed using resilient rubber rail boots or elastomeric grout. Pre-cast concrete in-street ties or composite ties should be used to secure the track gauge and form an integral part of the embedded track structure. Embedded Mainline track structures with and without guard rail systems are shown in Appendix 5A Figures 5.9A, 5.9B, and 5.10.

Installation of embedded track using elastomeric grout must include forming channels in the concrete slab to accommodate the running rails.

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

**5.2.2.8 Embedded Shop Track**

Embedded track, as shown in Appendix 5A Figure 5.11, should be used in maintenance facilities to allow for movement of maintenance equipment across the shop floor.

Rail fasteners for embedded Shop Track should 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 should be used to maintain track. Gauge rods must be electrically isolated. Vertical adjustments should be made by shimming.

Embedded Shop Track should be in-filled with grout or concrete. The field side in-fill grout or concrete elevation should be set 10 mm below the Top of Rail (TOR).

5.2.2.9 Pit Tracks
Pit tracks, as shown in Appendix 5A Figure 5.12, should be used for maintenance purpose when access for maintenance personnel is required in the undercarriage of an LRV.

A pit track system is comprised of rails directly fastened to the top of steel I-beams. Removable plates should 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 method of track transitioning must be considered wherever there is a change in track modulus.

<table>
<thead>
<tr>
<th>Track Type</th>
<th>Typical Track Modulus (μ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Tie and Ballast</td>
<td>21 N/mm² (3,000 lb/in²) or greater</td>
</tr>
<tr>
<td>Composite Tie and Ballast</td>
<td>21 N/mm² (3,000 lb/in²) or greater</td>
</tr>
<tr>
<td>Concrete Tie and Ballast</td>
<td>48 - 55 N/mm² (7,000 – 8,000 lb/in²) or greater</td>
</tr>
<tr>
<td>Direct Fixation</td>
<td>69 N/mm² (10,000 lb/in²) or greater</td>
</tr>
<tr>
<td>Embedded</td>
<td>69 N/mm² (10,000 lb/in²) or greater</td>
</tr>
</tbody>
</table>

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

The track transition should be over a minimum of three ties for all types of ballasted tracks.

5.2.3.1 Transition Ties
Transition ties may be used at approaches to bridge structures and at wood/composite to concrete tie interfaces. Refer to Appendix 5A Figure 5.13.

5.2.3.2 Transition Slab
Transition slabs should be used for transferring track stiffness from direct fixation to tie and ballast, or where space restrictions do not allow transition ties to be used. Refer to Appendix 5A Figure 5.14.

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 includes the following components:

- Turnouts and crossovers
- Diamonds
- Guard rails
5.3.1 General Requirements
All special trackwork must be located on tangent track with constant profile grade. Special trackwork components should be constructed of manganese.

For tie and ballast track, special trackwork must be placed on concrete ties.

For concrete slab track or concrete plinths, special trackwork should be incorporated on a direct fixation system using elastomeric grout pads.

For embedded track, special trackwork should not be placed due to O&M issues. Where necessary, a cut-out section should be designed where the special trackwork is placed as direct fixation track on concrete plinths or directly on the concrete track slab using elastomeric grout pads.

In maintenance facilities, switches on the shop floor should be of the in-street type of special trackwork and should be installed as an embedded track system to allow 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
Table 5.1 presents the maximum allowed speeds through turnouts from the AREMA Manual [1] for standard North American turnouts based on a maximum allowable unbalanced superelevation of 65 mm.

<table>
<thead>
<tr>
<th>Turnout No.</th>
<th>Location</th>
<th>AREMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 5</td>
<td>Mainline Track where space restrictions are imposed by track geometry</td>
<td>15 km/h</td>
</tr>
<tr>
<td></td>
<td>Yards and service areas</td>
<td></td>
</tr>
<tr>
<td>No. 6</td>
<td>Mainline Track where space restrictions are imposed by track geometry</td>
<td>20 km/h</td>
</tr>
<tr>
<td>No. 8</td>
<td>Mainline Track where high speeds are not required through the turnout</td>
<td>25 km/h</td>
</tr>
<tr>
<td>No. 12</td>
<td>Mainline Track where intermediate speeds through the turnout may be required</td>
<td>38 km/h</td>
</tr>
</tbody>
</table>

5.3.2.2 Turnout Geometry
Turnout geometry is influenced by the design of switch points and heel spread. Design standards for tangential turnouts should be used as illustrated in Appendix 5A Figure 5.15.

The minimum 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 restrictions should 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 must be adequately drained
- Turnouts adjacent to roadway crossings must not be located within 50 m of the edge of 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>
<thead>
<tr>
<th>Classification</th>
<th>Direct Fixation</th>
<th>Ballasted Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnout with diverging track running uphill</td>
<td>Maximum 2.0%</td>
<td>Maximum 1.5%</td>
</tr>
<tr>
<td>Turnout with diverging track running downhill</td>
<td>Maximum 2.0%</td>
<td>Maximum 1.5%</td>
</tr>
<tr>
<td>Crossover</td>
<td>Maximum 1.0%</td>
<td>Maximum 0.5%</td>
</tr>
<tr>
<td>Double Crossover</td>
<td>Maximum 0.5%</td>
<td>Maximum 0.3%</td>
</tr>
<tr>
<td>Yard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnout</td>
<td>Not applicable</td>
<td>Maximum 2.0%</td>
</tr>
<tr>
<td>Crossover</td>
<td>Not applicable</td>
<td>Maximum 0.5%</td>
</tr>
</tbody>
</table>

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

General requirements for crossovers are the same as those listed for turnouts in Section 5.3.2.

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

- Double crossover diamonds should be located on tangent parallel track
- The Designer must consider the proximity of track separation to avoid having the Train wheels crossing the unrestrained 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 should be fabricated from the same rail section as the running rail. The sliding rail joint baseplates should 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 should 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 Guard Rails
Guard rails must be installed for all horizontal curves of radius less than 200 m. Guard rails are installed on the gauge side of the low rail and should be tapered to guide the wheel flange in and out of the flangeway at the beginning and the end of the guard rail.

The flangeway gap between the running and guard rails should be adjustable (refer to Section 5.1.3.3).

5.3.8 Restraining Rails
Restraining rails must be installed on the gauge side of both running rails on aerial guideways and bridge structures. Restraining rails may 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. Restraining rails may be fabricated using part-worn rail. On direct fixation track, restraining rails may be directly fastened to the concrete slab or bridge deck. The centre of the restraining rail should be located 300 mm from the centre of the running rail.

Refer to Appendix 5A Figure 5.16 for typical restraining rail layouts and Appendix 5A Figure 5.17 for fastening details.

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 should cross as close to a right angle as possible. The crossing should 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 designing At-Grade crossings:
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 should be constructed on well compacted granular fill. Pre-cast concrete planks with rubber rail seals on composite ties should 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 acceptable track section should be a tee rail section with a rubber boot and a flangeway insert in elastomer or on a concrete slab.

Refer to Appendix 5A Figure 5.18 for a typical At-Grade road crossing design.

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 should be constructed as an embedded Mainline track structure. The acceptable track section should be a tee rail section with rubber boot and a flangeway insert.

Refer to:
- Section 5.2.2.7 for embedded Mainline track requirements
- Section 5.3.7 for guard rail requirements
- Section 5.6.9 for track lubricator requirement on curved track

5.4.3 Pedestrian Crossings
Pedestrian crossings should use a pre-cast crossing panel design with a surface specific to pedestrians. Cast-in-place crossing panels may be used. Where cast-in-place crossing panels are selected, wood ties are not acceptable.

Pedestrian crossing geometry must be considered with the Engineer and the Operator.

Refer to Appendix 5A Figure 5.19 for a typical pedestrian crossing design.

5.4.4 Service Life and Maintenance
The service life of a crossing should be a minimum of 25 years.

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

5.4.5 Corrosion Protection
Boots or shields covering the fastening components should be incorporated in the flangeway on both the gauge and field side of the rail to protect the fasteners from material that would cause a current leakage.
Grounding at the vicinity of the At-Grade crossing should be considered to mitigate corrosion caused by current leakage.

## 5.5 TRACK COMPONENTS

### 5.5.1 Running Rail

Standard control-cooled carbon steel rails with minimum 300 Brinell Hardness, manufactured in accordance with the AREMA Manual [1], should be used for running rails. Refer to Appendix 5A Figures 5.20A to 5.20C.

The LRV wheel profile is shown in Figure 5.21 and the work train wheel profile is shown in Figure 5.22, both in Appendix 5A.

#### 5.5.1.1 Rails for Mainline Track

Running rail for Mainline track should be rolled 115 lb RE (57.2 kg/m) rail (refer to Appendix 5A Figure 5.20B).

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

New running rails on Mainline must be CWR. CWR must be properly destressed and laid in accordance with the optimum neutral rail temperature in order to minimize the destressing requirement.

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

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

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

#### 5.5.1.2 Rails for Special Trackwork

Rail used for the manufacture of special trackwork on Mainline track should be rolled to 115 lb RE (57.2 kg/m) rail. Welded boltless manganese frogs should be used. In areas where there are high impact loads, rail should be hardened to 340 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 should meet the following requirements:

- Rail for Pocket Track should be 115 lb RE (57.2 kg/m) CWR rail
- Rail for Yard Track should be 115 lb RE (57.2 kg/m) CWR or bolted rail
- Rail for Shop Track should be 115 lb RE (57.2 kg/m) CWR, or 67R1 (Ph37a) girder rail

Girder rail used as in-street special trackwork for Shop Track should have a flangeway width to accommodate both the LRV wheel and the work Train standard AAR wheel.
5.5.2 Fastening Devices

5.5.2.1 Direct Fixation Fasteners
Elastomeric bonded plate fasteners should be used for direct fixation track. The plate type fastener should 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 should be chosen with the ability 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
- Reduce 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 should be manufactured from rolled steel plate and should have shoulders to provide rail seating for 115 lb RE rail. Baseplates should 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 the 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 ensure the bolt will not be loosened or be placed in bending under service conditions.

The design of the anchoring assembly should 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, as shown in Appendix 5A Figure 5.23, are cast directly into the concrete base slab as the hold-down connection for mating anchor bolts. The insert should be designed and installed to match the bearing strength of the plinth or slab.

Inserts should 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 should 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 should 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 should not be considered except for special trackwork installations as necessary.

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

5.5.2.6 Steel Shims
Steel shims should 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 should be manufactured from galvanized steel, coating designation G60 (458 g/m²), in accordance with the requirement of ASTM A527-80. Steel shims of 6 mm, 10 mm, and 20 mm thicknesses should be manufactured from hot-rolled plate steel in accordance with CSA G40.21M, Grade 260. The thickness requirements should include galvanization. Steel shims should be hot dip galvanized in accordance with the latest edition of CSA G164-M. Galvanizing should be applied to a minimum 610 g/m² coating on both sides after manufacture. The shape, size, and configuration of the steel shims should conform to the outline of the direct fixation fasteners.

Refer to Appendix 5A Figure 5.24 for shim details. Typical details for concrete plinths are shown on Figure 5.25A to 5.25C in Appendix 5A.

5.5.3 Ties
5.5.3.1 Wood Crossties
Wood crossties used in Yard Track should be softwood. Refer to Appendix 5A Figures 5.26. In areas where maintenance access is restricted, hardwood ties should be used. Anti-splitting devices should be installed at the tie ends on all hardwood ties and should conform to AREMA requirements. All wood crossties should be pressure treated in accordance with the AREMA Manual [1].

The standard nominal dimensions for wood crossties should be:

- Depth – 180 mm (7in.)
- Width – 230 mm (9in.)
- Length – 2600 mm (6-8in.)

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 should 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 should be hardwood.

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

All wood switch ties should be pressure treated in accordance with the AREMA Manual [1]. 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 should 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 should be used at transition points between wood and concrete ties. Refer to Section 5.2.3. Composite transition ties should be spaced at 500 mm on centre.

The standard nominal dimensions for composite transition ties should be:

- Depth – 180 mm (7in.)
- Width – 230 mm (9in.)
- Length – varies according to the layout (refer to Appendix 5A Figure 5.13)

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 should be positioned in the screw spike holes to isolate the screw spikes from the base plate.

5.5.3.4 Concrete Crossties
Concrete crossties should be mono-block prestressed, reinforced concrete ties conforming to the current AREMA Manual [1]. A typical concrete crosstie is shown in Appendix 5A Figure 5.27.

Precast concrete crossties should be designed to conform to practices specific in CSA A23 and should provide:

- Cast iron rail seat shoulders 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
- Electric isolation

Adjustments designed to permit gauge widening can be considered unless otherwise specified.

Tie spacing in curves with a radius less than 300 m should be reduced by 75 mm. A track structure analysis is required prior to making tie spacing adjustments. Refer to Section 5.2.1.1.

5.5.3.5 Concrete Special Trackwork Ties
Concrete switch ties should be used for Mainline turnouts. Concrete switch ties should 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 Crossties
Composite crossties used on road crossings should be composed primarily of post-consumer recycled HDPE conforming to the AREMA Manual [1].

The standard nominal dimensions for composite crossties should be:

- Depth – 180 mm (7in.)
- Width – 230 mm (9in.)
- Length – 2600 mm (6-8in.)
Consideration should be given to isolating the rail from the surrounding track structure in areas adjacent to underground utilities, ducts, and other structures. Insulators should be placed at the base of the tie plate and insulating thimbles should be positioned in the screw spike holes to isolate the screw spikes from the base plate.

Typical lateral track bracing details at Platforms are shown in Appendix 5A Figure 5.28.

### 5.5.4 Ballast
Ballast used for the tie installation must comply with the requirements of the AREMA Manual [1]. 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 should be granites and quartzites. Dolomite must not be used. The ballast specification should provide a 100% crushed ballast conforming to AREMA No. 3 gradation. Ballast should be placed to a minimum depth of 225 mm below the bottom of the tie. Ballast of finer gradation should be used in transition slab area where the space between the bottom of the tie and the slab restrict the tamping of ballast effectively.

### 5.5.5 Sub-ballast
Sub-ballast used for trackwork must comply with the current AREMA Manual [1]. Sub-ballast must have suitable mechanical, chemical, and environmental characteristics and permeability. Crushed stone, crushed gravel and sands, or a mixture of these materials should be used as sub-ballast materials. Sub-ballast should 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 should 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 should 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.

Appendix 5A Figure 5.29 shows typical details for two standard ballast curb cross-sections.

### 5.6 OTHER TRACKWORK MATERIALS

In addition to the major track components described previously, the following devices are typically installed. These devices must ensure electrical isolation to prevent 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 should 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.

Switch machines should 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.

### 5.6.2 Switch Blowers

Switch blowers should 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 should be incorporated as an integral part of special trackwork fabrication by the special trackwork supplier and be specified during the procurement process. Appendix 5A Figure 5.30 provides typical details of the hold-down bar requirements.
5.6.5  **Roller Plates**
Roller plates should 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**
A switch point protector should be incorporated in all turnouts where the turnout curve is designated as Mainline operation and the Train movement is predominantly a facing point movement. They should also be incorporated as an integral part of special trackwork fabrication by the special trackwork supplier. Appendix 5A Figure 5.31 provides the typical details of a switch point protector.

5.6.7  **Friction End Stops**
Friction end stops must be installed at the end of all Mainline track. Friction end stops must be able to withstand the impact load of a run-away Train 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. Refer to TCRP 155 [2].

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 should be installed at the end of Yard and Shop Track. Wheel stops should be of a rail-mounted type or directly welded onto the railhead and must be able to withstand a 5 km/h impact load 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 should 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 in providing remote sensing and diagnostics for system malfunctions
- Protection against vandalism
- 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 electric 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. The typical spacing and bracing requirements are as shown in Appendix 5A Figure 5.4 and Appendix 5A Figure 5.29.

5.6.11 Rail Anchors
Rail anchors should 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 the thermal and vehicle dynamic braking.

Appendix 5A Figure 5.26 provides the typical details of a rail anchoring system.
APPENDIX 5A – FIGURES
NOTE:
- Dimensions may vary in accordance with the top of rail, elevation relative to the finished ground level outside trackway.
- Refer to Figure 3.13 for combined major trackway elements.
- Refer to Figure 5.28 for typical ballast curb typical details.
- Subgrade to be scarified. Placement of geotextile on sub-grade as directed by the consultant.

FIGURE 5.1
BALLASTED TRACK AT-GRADE MAINLINE (CONFINED)
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NOTES:
- Concrete or composite ties are preferred option for mainline track.
- Wood ties are preferred option for yard track.
- Placement of geotextile fabric on sub-grade as directed by the consultant.

FIGURE 5.2
BALLASTED TRACK AT-GRADE
MAINLINE AND YARD (OPEN)
NOTES:
- Dimensions may vary in accordance with the top of rail elevation relative to the finished ground level outside trackway.
- Refer to Figure 3.15 for combined major trackway elements.
- Refer to Figure 5.28 for typical ballast curb details.

FIGURE 5.3
BALLASTED TRACK AT-GRADE ON CONCRETE SLAB MAINLINE (CONFINED)
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FIGURE 5.4
BALLASTED TRACK ON CONCRETE SLAB STATION STRUCTURE

NOTE:
- REFER TO FIGURE 3.20 FOR COMBINED MAJOR TRACKWAY ELEMENTS.

100x100 PRESSURE TREATED TIMBER BRACING (SEE FIG 3.20 FOR DETAILS.)

NOTE:
- REFER TO FIGURE 3.20 FOR COMBINED MAJOR TRACKWAY ELEMENTS.

DATE
REV. 1

DATE
REV. 1
NOTE:
- Refer to Figure 3.15 for combined major trackway elements.

FIGURE 5.5
DIRECT FIXATION MAINLINE TRACK WITHOUT GUARD RAIL

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NOTE:
- REFER TO FIGURE 3.17 FOR COMBINED MAJOR TRACKWAY ELEMENTS.
NOTE:
The minimum dimension is based on tangent track with no super-elevation.

Refer to Figure 5.16 for combined major trackway elements.

FIGURE 5.7
DIRECT FIXATION ON CONCRETE SLAB
TBM TUNNEL STRUCTURE
NOTE:
* REFER TO FIGURE 5.18 FOR COMBINED MAJOR TRACKWAY ELEMENTS.
FIGURE 5.9B
EMBEDDED MAINLINE TRACK WITH GUARD RAIL
FIGURE 5.10
EMBEDDED TRACK ROAD/PEDESTRIAN CROSSING WITH GUARD RAIL
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FIGURE 5.13
TYPICAL TRANSITION TIE LAYOUT
FIGURE 5.14
TYPICAL TRANSITION SLAB DETAILS

CHAPTER 5
TRACKWORK
### Figure 5.15

#### Turnout and Crossover Data for Curved Split Switches

**Aremo Standard**

<table>
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<th>Date</th>
<th>Revision</th>
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</thead>
</table>

**Table:**

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<th>Turnout Type</th>
<th>Curve Radius (m)</th>
<th>Track Spacing (m)</th>
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<tr>
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<td>300</td>
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</tr>
<tr>
<td>6</td>
<td>Right</td>
<td>700</td>
<td>5.5</td>
</tr>
</tbody>
</table>

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FIGURE 5.16
TYPICAL RESTRRAINING RAIL
LAYOUT PLAN
DIRECT FIXATION TO CONCRETE DECK

BALLASTED TRACK

FIGURE 5.17
TYPICAL RESTRANING GUARD RAIL FASTERNERS
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NOTE:
* DENOTES DIMENSIONS ARE SUBJECT TO MANUFACTURER’S SPECIFICATIONS.

FIGURE 5.18
TYPICAL AT-GRADE ROAD CROSSING

Date  Revision
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FIGURE 5.21
LIGHT RAIL VEHICLE WHEEL PROFILE

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LRT DESIGN GUIDELINES
FIGURE 5.23
TYPICAL 1:40 CANTED DIRECT FIXATION FASTENER AND ANCHORING ASSEMBLY

NOTES:
* For construction purposes centreline of fastener is equal to centreline of standard 650x1200 plinth
** Dimensions to be confirmed.
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FIGURE 5.24
TYPICAL SHIM DETAIL FOR DIRECT FIXATION FASTENER

NOTES
* DIMENSIONS AS SHOWN ARE BASED ON L.B. FOSTER D.F. FASTENER MODEL F3334. CURRENTLY USED IN THE SYSTEM. DIMENSIONS TO BE CONFIRMED IF OTHER D.F. FASTENER IS USED.

HOLDS SLOTTED AS SHOWN TO AID IN INSTALLATION AND REMOVAL OF SHIM.
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FIGURE 5.25B
TYPICAL 650 mm x 1200 mm CAST-IN-PLACE PLINTH
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BALLAST CURB – TAPERED

BALLAST CURB – TRANSITION TO RETAINING WALL

FIGURE 5.29
BALLAST CURB TYPICAL DETAILS
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FIGURE 5.30
TYPICAL HOLD-DOWN BAR

BILL OF MATERIAL

ITEM
1. 22 BAR - 1 1/8" THICK X 2 1/2" WIDE X 4 1/2" - 5 1/2" LONG
2. SQUARE PLATE 1/2" THICK X 2 1/2" WIDE X 9 1/2" LONG
3. FERRITE PLATE 1/4" THICK X 2 3/4" WIDE X 10" LONG
4. FIRE BRUSHING 7/32" THICK X 1 1/32" OD. X 1 1/32" LONG
5. 3/4" OAL - 10 LONG SQ. HB BOLT X 4 1/4" LONG G/W HOLE NUT
6. 3/16" COTTER PIN X 1/4" LONG
7. 10-MA - 60 DEGREE DRAWFITTING
8. 1 SPACER BLOCK 2 1/2" X 2 1/2" X VARIOUS THICKNESS (SEE NOTE #1)
9. 1 STUD HANGER - VARIABLE DEPTH (SEE NOTE #2)
10. 1 3/4" OAL - 10 LONG HD. 10 OAL X 5 1/4" LONG G/W HEX NUT (LENGTH WAY MAND)
11. 2 1/2" OAL - 12 LONG HD. 10 OAL X 5 1/2" LONG G/W HEX NUT (LENGTH WAY MAND)

NOTES:
- TO BE USED FOR INFORMATION ONLY
- THIS HOLD-DOWN BAR DESIGN IS CURRENTLY USED ON THE EXISTING EDMONTON LRT SYSTEM
- ALL DIMENSIONS ON THIS DRAWING ARE IN INCHES UNLESS OTHERWISE NOTED

DETAIL OF ITEM 2
DETAIL OF ITEM 3

DETAIL OF ITEM 4

NOTES:
1. ALL IRON PARTS MUST BE REMOVE
2. ALL METAL PARTS IN CONTACT WITH INSULATION SHALL HAVE SHARP EDGES REMOVED BEFORE ASSEMBLY
3. ELECTRICAL INSTALLATION, ELECTRIC TESTS SHALL BE MADE WITH INSULATION EMU. ASSUMED INSULATED TRACE FITTING SHALL BE MADE IN THE ASストレスLESS THAN 3 SECONDS ON INSULATED REVIE OF 1500 VOLTS AC WITHOUT FAULT OCCURS ON UNCONTAINED IN METALLIC PARTS & COVER METALLIC PARTS INSULATED FOLUTION.
4. ALL METAL PARTS SHALL BE SHIELDED. A TEST TO DETERMINE WOMAN VERIFIED FOR THE CANTING OR HOLE IN THE MANUFACTURING OF SWITCH RODS IS ABSOLUTELY HOPPERED.
5. BAR STOCK TO CONFORM TO THE LATEST REVISION OF ASTM STANDARD FOR MERCHANT QUALITY HOT ROLLED BAR STEEL.
6. THICKNESS MAY VARY WITH DIFFERENCES BETWEEN BASE OF SWITCH POINT AND EDGE OF STOCK RAIL.
7. DEPTH MAY VARY ACCORDING TO ENGINEERING BETWEEN BASE OF SWITCH ROD AND EDGE OF STOCK RAIL.
8. INSULATED CIRCUIT BOARD, IF REQUIRED AS READER IN VARYING THAN 1 1/2" TO SPACE BETWEEN STAK M RAIL BASE AND HOLD DOWN BAR WILLY VARY IN ACCORDANCE WITH READER PLATE, MAXIMUM HEIGHT.
9. ALL METAL PARTS SHOWN IN THE ACCORDANCE WITH SWITCH RAIL BASE (CONFIRM BY FIELD MEASUREMENTS).
FIGURE 5.31
TYPICAL SWITCH
POINT PROTECTOR
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6.0 TRACTION POWER

6.1 INTRODUCTION

This chapter outlines design guidelines for the LRT Traction Power System (TPS). The TPS includes Traction Power Substations (TPSS), the Power Distribution System (PDS), the Overhead Contact System (OCS), and 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 presented in Chapter 11, Electrical.

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

6.1.1 System Description

The TPS is comprised of electrical substations, 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 (LRV).

TPSS converts medium voltage (MV) Alternating Current (AC) power from the utility provider to low voltage DC power for Trains. From the substation, 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 which ensures public safety.

6.1.1.1 Future LRT Extensions and System Renewal

Design of LRT System extensions and future renewal projects must include consideration for the TPS to accommodate the following:

- Mitigation of visual impact and achieving an acceptable level of Sustainable Urban Integration (SUI) as described in Chapter 14, Urban Integration, while considering the corridor type as outlined 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 length described in Chapter 2, Vehicles and minimum headways outlined 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 in a primarily suburban residential setting. Including factors such as noise, speed, overall appearance of the system, and code clearances as outlined 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 Signals 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.

- **CEC**  
  Canadian Electrical Code [1]
- **NFPA 130**  
- **IEEE**  
  Institute of Electrical and Electronics Engineers
- **CSA**  
  Canadian Standards Association
- **ASTM**  
  American Society for Testing and Materials

6.1.3 Traction Power System Elements

6.1.3.1 Traction Power Substation

The TPSS converts AC power from the utility service provider to DC power for the LRT System, which 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 VDC protection and control power system
- Positive and negative disconnect switches
- DC positive and negative power cables
- Rail ground switch
- Programmable Logic Controllers (PLC) substation controllers
- Supervisory Control and Data Acquisition (SCADA) systems

6.1.3.2 Power Distribution System

The PDS connects a substation’s positive circuit to the OCS and the negative circuit to the rails, which includes the following primary elements:

- DC positive and negative feeder cables
- Positive Feeder Switches
- Positive Tie Switches
- Underground duct banks
- Cable raceways

6.1.3.3 Overhead Contact System

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 Traction Power System 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 are to 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 substations under all operating scenarios to ensure that system DC voltages are maintained above the 480 V\textsubscript{DC} minimum LRV operating voltage at the LRV pantograph, rail to ground voltage does not exceed maximum permissible limit of 100 V\textsubscript{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 system wires are to be modeled at their 30% worn condition.

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 use different limits as necessary to suit actual site conditions.

The Designer is responsible for ensuring suitable placement of substations based on variables and assumptions included in the Load Flow Study.

### 6.1.5 Traction Power System Loads and Parameters

New substations, 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 new or existing TPS using the physical and operational aspect of the proposed additions under multiple operating scenarios. Results of the study must ensure that the power system is designed to satisfy the desired operational performance criteria using 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.

<table>
<thead>
<tr>
<th>Table 6.1 General Load Flow Vehicle Requirements</th>
</tr>
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<tbody>
<tr>
<td><strong>Motoring Current Per LRV</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>Acceleration Current Per LRV</strong></td>
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<tr>
<td><strong>Peak Hotel Power</strong></td>
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<tr>
<td><strong>Minimum Operating Voltage</strong></td>
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<tr>
<td><strong>Absolute Minimum Voltage</strong></td>
</tr>
<tr>
<td><strong>Absolute Maximum Voltage</strong></td>
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</table>

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

- TPS nominal voltage: 670 V\textsubscript{DC} (Future 710 V\textsubscript{DC})
- TPS no-load voltage: 710 V\textsubscript{DC} (Future 750 V\textsubscript{DC})
The TPSS equipment is designed to be flexible in its ability to increase nominal and no-load DC output voltage to support potential future voltage increase opportunities. The TPS must be designed to accommodate the full acceleration and half acceleration criteria outlined in the below sections.

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 substations in service, the TPS must be modeled to ensure that the voltage level supplied to the Trains remains above the system low voltage limit of 480 V$_{DC}$. This scenario is evaluated for each Station included in the zone of the system being evaluated or affected.

The Designer must coordinate full acceleration load flow operating conditions with the Engineer. The TPS operational conditions shown below 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 substation removed from service. With a substation out of service and bypassed, two adjacent substations 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 simultaneously stopped and started at the midpoint of an affected section. This test is performed to ensure that the TPS voltage measured at the pantograph for each Train is maintained above the system low voltage limit of 480 V$_{DC}$. Half acceleration analysis is to be repeated for each new substation and the immediate adjacent substation on the existing system being extended or altered. For Terminus substations, half acceleration analysis is to be performed with a single Train accelerating from the Terminus Station. The voltage to the Train is to 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 lowered 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
Dynamic vehicle clearance analysis for the OCS design to be coordinated with the Design Vehicle Dynamic Envelope (DVDE), as outlined in Chapter 3, Clearances and Right-of-Way
- Behaviour of supporting structures under static and dynamic loading
- Pantograph security analysis
- Electrical interference with electronic devices
- Electrical interference with health & safety standards
- Impact of TPSS noise

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

6.2 TRACTION POWER SUBSTATION

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 life expectancies with the overall LRT System life expectancy
- Consider “lessons learned” from design of previous substations
- Standardize all major equipment as much as practical
- Coordinate new facility design with existing systems
- Ensure operational and load requirements are not compromised in terms of capacity, reliability, or maintainability of the system
- Maintain consistent TP protection and control systems operational performance, and philosophy as with existing substations

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 are to be developed through detailed design and are required to inform 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 and touch potential analysis
- Lightning/surge 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 ensure that all TP equipment and cables are rated for the maximum available fault currents on the system. 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 to ensure that all TP equipment and cables are protected, and all protection elements are coordinated to operate effectively during ground fault, phase fault condition, and/or DC current faults.

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.

6.2.2.4 Step and Touch Potential Analysis
A step and touch potential analysis must be performed to establish the ground grid design in and around the TPSS. The grid must be designed to ensure that safe step and touch voltages are maintained 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

The analysis must follow the IEEE Std 80, Guide for Safety in AC Substation Grounding [3].

6.2.2.5 Lightning/Surge Analysis
A lightning/surge analysis must be performed to confirm that lightning and surge protection devices are designed to withstand maximum local lightning and surge values.

6.2.3 Substation Facilities
6.2.3.1 Substation Types
The LRT System uses three types of substation facilities: within a Utility Complex, as a stand-alone building, and integrated within a Station.

Utility Complex
A Utility Complex is a single building where Signals, communications, electrical distribution, and other rooms are provided at the same location where the TPSS and other systems rooms must be combined. At these Utility Complexes, the TPSS must power a dry type Station service transformer for standby power to the building and LRT ROW.

Stand-Alone
Where other system rooms are not required, a stand-alone TPSS must be located in a separate structure between or near Stations. Where a temporary or short-term TPSS is required, a portable (pre-fabricated) substation may be used as a stand-alone substation.

Integrated
Where appropriate, substations 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\textsubscript{DC} switchgear
A negative disconnect switch
A rail ground switch
125 V\textsubscript{DC} battery bank and chargers
125 V\textsubscript{DC} control power system
Local PLC
A local Human Machine Interface (HMI) annunciation panel
A communications cabinet that houses the SCADA system, including:

- A remote terminal unit
- Network equipment
- A fibre patch panel

A substation grounding system to include adequate ground grids
Fire alarm and intrusion detection systems
Heating and ventilation systems (if stand-alone or portable)
Station service equipment (if standalone or portable)
A first aid kit
An eye wash station

In some instances, substations 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 substation. If dual transformers are provided, either unit should be capable of carrying the entire load of the substation. 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 Medium Voltage (MV) feeders originating from different utility substations, or at a minimum, from different supply buses in the same substation. 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 allows 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 the TPSS or Utility Complex may not be available or may be considered to be an expensive project cost. At these locations, the TPSS designs will include provisions for an alternate feed should one become available in the future. This includes space for the 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 provision of 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 Utility Complex. As part of a Utility Complex, 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 substations, a stepdown transformer designed into the MV switchgear must provide standby Station service power to the substation building.

6.2.3.6 Substation Control Power
Each substation must be equipped with an auxiliary power supply system to provide nominal 125 V\textsubscript{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 ensures power is provided 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. Valve regulated lead acid battery technology must be used to minimize hydrogen emissions, therefore eliminating the need for specialized room and 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 service and ducts attached to the face of the tunnel walls or MV installations within the 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
- 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 possible, 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 a minimum of three nylon pulling strings 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 (except for the DC switchgear, rectifier enclosures and positive feeder line, and bypass switches) must be bonded to ground to eliminate touch potential. The TPSS ground grid must extend to the exterior to ensure that all conductive and non-current carrying objects within 2 m of the substation are bonded. All grounding conductors must be sized and installed in accordance with the CEC [1]. The maximum TPSS ground resistance must be 1 Ω.

6.2.4 Substation 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 substation 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 2.0 MVA transformer-rectifier units should be installed. This change reduces redundancy while maintaining the load capabilities in anticipation of future operations.

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

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

6.2.4.1 Operating Conditions
TPSS equipment must be located indoors in a room classified as non-hazardous. Operating temperature range for equipment is 0° C to +40° C and site elevation is per 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 [4] 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: 600 or 1200 A
- Frequency: 60 Hz
- Basic Impulse Level: 110 kV
- Fault Interrupting Capacity: 31,000 A (750 MVA) to be confirmed with fault levels available from the local utility provider
- Arc resistant accessibility type 2C

AC switchgear must conform to the latest edition of the utility provider’s customer connection guide, such as the EPCOR Customer Connection Guide [5].

Utility metering cells are required for each incoming service.

Metering transformers are to 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 onsite generator, gang operated isolating switches with contact operation verifiable by direct visible means must be installed. These isolating switches are to 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 will only 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 substations 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 substation feeder. This provides additional redundancy in the OCS network, allowing Trains to continue to operate on a single feeder in the event of losing a single substation.

DC switchgear must be isolated from ground either by a glastic 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 clad and must be built in accordance with IEEE 37.20 [4].
Standard ratings for the LRT System DC switchgear are:

- Nominal voltage: 750 V<sub>DC</sub>
- Maximum voltage: 1000 V<sub>DC</sub>
- 60 Hz withstand voltage: 3700 V<sub>AC</sub> (RMS)
- DC withstand voltage: 5200 V<sub>DC</sub>
- Continuous current rating: 6000 A<sub>DC</sub>
- Main breaker current rating: 6000 A<sub>DC</sub>
- Feeder breaker current rating: 4000 A<sub>DC</sub>
- Peak closing and latching current: 200 kA<sub>DC</sub>
- Rated short circuit current: 150 kA<sub>DC</sub>

These ratings are to 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 [6]. Standard ratings for the LRT System rectifiers are:

- Output: 2000 kW, 660 V<sub>DC</sub>, 3030 A<sub>DC</sub>, continuous
- Overload rating of 150% for 2 hours
- Overload rating of 300% for 1 minute

Rectifiers are to be isolated from ground either by a glastic 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 have an N-1 rating, natural convection cooling, and full wave diode bridges providing 12-pulse rectification.

Rectifiers must be designed to meet heavy traction service as per IEEE 1653.1 [7], 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 is to be designed to operate as a coordinated set with the rectifier and transformer. The interphase transformer is to 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 [7], 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 will be mechanically interlocked with their associated DC main breaker to ensure they cannot be operated 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.

6.2.4.6 Rectifier Transformers
The rectifier transformer, rectifier, and interphase transformer are to 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 [7], 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 [8]
- 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 the 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
• Primary to secondary Y impedance: 6.3%
• Primary to secondary Δ impedance: 6.3%
• Winding material: copper
• Voltage regulation not greater than 6% from 1% load to full load

6.2.4.7 Rail Ground Switch
A Rail Ground Switch (RGS) in each substation 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 duration, 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 currents (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 substation PLC

6.2.4.8 Auxiliary Power Supply System
A 125 VDC auxiliary power system is used for the basic substation controls, relaying, SCADA 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 should be properly designed, safeguarded and maintained, and the emergency requirements should be carefully estimated to ensure 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 VDC
• 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.

1 The transformers are to 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 have been added at -7.5%, -10%, and -12.5%.
6.2.4.9 Wiring Methods
Wire installations must be designed as per the CEC [1].

Cable in tray is the preferred method 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 are to be verified by the Designer. Typically bus bar and bus connectors on the LRT System are sized as follows:

- For 1000 VDC switchgear – 6000 A<sub>DC</sub> continuous
- For MV AC switchgear – 600 or 1200 A continuous

6.2.5 Substation Status and Control
All substations must be equipped with a PLC to provide local and remote control of substation equipment. The PLC must communicate with an HMI display that provides local active single line display, annunciation, 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 must communicate directly with the Remote Terminal Unit (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 Substation Programmable Logic Controller and Local Human Machine Interface (HMI) Annunciation
Each substation must be equipped with a local Programmable Logic Controller (PLC) and local annunciation must be provided by the Human Machine Interface (HMI) display unit for the following 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<sub>DC</sub> 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 substation design
• Emergency trip station status
• All lockout relay alarms and status

6.2.5.2 SCADA Remote Terminal Unit
The Remote Terminal Unit (RTU) must be equipped with dual output, typically over ethernet. One output is to be used by the Operator only to monitor the required substation 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 status
• Transformer status
• Rectifier status
• RGS status
• DC feeder and Tie Switch status if switch bank is included in the substation design
• 125 VDC auxiliary power system status
• Emergency trip station status
• SCADA failure
• PLC failure
• Lockout relay status

All substation device status, control, and alarm indication signals should be routed to the substation 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.

6.2.5.3 Substation/Utility Complex Building Systems
In addition to the items listed above, the following building status information must be communicated to the RTU:

• Fire alarm
• Substation intrusion alarm
• Building 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 coordinating the above listed points with systems monitoring.
Fire and Smoke Detection System
All substations 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 substations. Where fire suppression is required, such as in substations 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
Standalone substations must be equipped with a full intrusion detection alarm system, with remote monitoring capabilities. Integrated substations 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 substation to maintain an indoor temperature range of 15°C to 25°C. The HVAC system Design must be coordinated with heat rejection calculations for the substation electrical equipment. Active cooling may be required if a maximum temperature of 25°C is not achievable with natural ventilation. Heating and ventilation systems must be powered through the TPSS service supply.

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 substation 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 VDC 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

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 VDC 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

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 (as back-up to RGS protection)
- DC lock-out relay
- PLC failure

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 standalone 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 Over-Voltage Protection
The rail to ground potential must be monitored to ensure that the public and ETS personnel are protected against unsafe rail to ground voltages. A Rail Ground Switch (RGS) in the substation 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 ensure that safe touch potential standard limits and durations are followed.

The RGS must consist of a fast-acting thyristor solid state switch paralleled with a contactor to provide continuous current support, be designed to withstand the maximum currents (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, and communicate with the substation 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 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 reclose 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 ensures the breaker is locked out if a subsequent fault occurs during a pre-set period following a successful reclose. The protection scheme must ensure the line test resistors do not exceed 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 currents 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 currents below the FMR overcurrent settings. The FMR must be adjustable with respect to current rate-of-rise \( \frac{di}{dt} \) 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 substation 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 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 a scenario where 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 substations 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 substation PLC. The PLC must initiate a mass trip clearing all the MV AC rectifier breakers and TP DC breakers in the substation, sending a transfer trip to adjacent substations. In the event a rectifier main bus faults to frame, this protective relay must detect the fault, sending a trip signal to the substation 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 substation PLC.

6.2.7.11 Substation 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 substation. Surge protection devices must be adequately rated for maximum voltage and fault current available. 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 substation equipment. For each DC positive and negative circuit entering the substation, 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 will 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 ensure output voltage does not become 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.

6.2.7.15 Transformer Thermal Protection
The rectifier transformers must use an adjustable two-stage thermal alarm and trip protection scheme. This protection device should use thermocouples for temperature measurement installed in each of the transformer’s three coils.

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 substation. When a substation is removed from service, the transfer trip protection must bypass the substation out of service and communicate between the two adjacent substations supporting the OCS section with the substation out of service.

6.2.7.17 Emergency Trip Stations
Emergency trip stations are used within substations and OMF to allow maintenance personnel the ability to quickly de-energize an entire substation 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.

Mainline
Emergency trip stations must be provided in all substations. 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 substations, de-energizing the OCS on both sides of the substation. Emergency trip stations must be located near each man door in an area that is easily accessible within each substation, and clearly identified as an emergency trip station. The trip station must be designed with a guarded pushbutton to prevent accidental operation.

Operation Maintenance and Storage Facility (OMF)
Emergency trip stations must also be provided at all maintenance and storage facilities. Activating the emergency trip station will typically 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 a maintenance facility, as well as in the yard. Emergency trip stations must be easily accessible, and must be clearly identified as an emergency trip station. The trip station must be designed with a guarded pushbutton to prevent an accidental operation.

6.3 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.
6.3.1 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 are to be determined by the Designer. For open LRT Trackways refer to Chapter 1, General for environmental conditions.

6.3.2 Positive Feeder Arrangement (Mainline)
For ease of switching during maintenance, connections of the OCS to substation DC breakers have been standardized. For Mainline substations, positive feeder #1 of one substation supplies power to the same OCS section as feeder #3 of an adjacent substation. Similarly, feeder #2 of one substation supplies power to the same OCS section as feeder #4 of an adjacent substation. This arrangement is maintained as substations are added to the system. For substations where two lines join, the numbering system may be unique.

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

6.3.3.1 Open Line Applications
The DC feeder cable conductor size is to 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 kVAC/2.5 kVDC.

6.3.3.2 Tunnel Applications
Additional feeder cables may be installed in tunnel sections to provide improved electrical support to the OCS. NFPA 130 [2] 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 kVAC/2.5 kVDC. Cable materials must comply with NFPA130 [2] requirements for fire resistance and low smoke.

6.3.4 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 guard rail installations. Cross Bonding between rail and track is required at substation locations and at midway points between substations. Bonding promotes current sharing between adjacent tracks and each running rail.

The quantity, size, connection requirements, and location of rail and Cross Bonds is to 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.
6.3.4.1 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<sub>AC</sub>/2.5 kV<sub>DC</sub> XLPE.

6.3.4.2 Tunnel Applications
NFPA 130 [2] 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<sub>AC</sub>/2.5 kV<sub>DC</sub>. Cables must meet NFPA 130 [2] 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.

6.3.5 Medium Voltage AC Power Cables
Medium Voltage (MV) AC power cables must be shielded cable rated for the utility provider 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 is to 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 [7]. Appropriate heat shrink or cold shrink stress cones must be used at cable ends.

6.3.6 Electrical Switches
For new Mainline substations, 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 substation’s DC feeders. The DC feeder cables make their first point of entry into the substation 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 ensure that they cannot be operated 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 substation protection and control scheme.

For PDS renewal of existing substations, upgrades should be performed in a manner that relocates feeder and Tie Switches from pole mounted locations to enclosures in a centralized location outside the substation. Electrical interlocks with upstream feeder breakers are still required along with a frame fault protection relay. Switches, and their operating handles, must be designed to withstand mechanical forces necessary to operate in temperatures as low as -40° C.

For OMF locations, or areas where additional switching/isolation is required, pole and wall mounted switches may be installed using key interlocks 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 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
6.3.7 DC Contactors and Ground Switches

In maintenance facilities, the OCS 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 Owner. They are grouped together and mounted in proximity to the area they are controlling. Each contactor and ground switch are 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 for faults above rated current
- Isolation of equipment from substation supply through complete removal of upstream fuse disconnects
- A motorized ground switch tied to maintenance facility main ground network
- Electrical interlock between contactor and ground switch to ensure safe operation
- Full auxiliary system interface including emergency push buttons, energization warning horns and strobe lights, and catenary indicator lights
- Electrical interlock with any access gates leading to overhead gantry access
- Ability to lock out ground switch in closed position to prevent unwanted re-energization of OCS
- Communication interface with upstream substation 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 be housed in separate cabinets. This will allow the Contactor to be installed at an elevated location away from Operators. For contactors servicing yard zones, lighting arrestors are required on the catenary side of the contactor to protect the upstream contactor and grounds switch system. Each ground switch must be housed such that its position can be viewed by operators to confirm closing of the ground switch. Control and PLC systems should be housed at operator height.

6.3.8 Cable Splices and Terminations

Cable splices must use approved splice kits and conform to CSA C22.2 No 188 [9] and CSA C22.3 No 1 [10]. 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.

6.4 DUCT BANKS AND RACEWAYS

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

- Underground supply feeders to be installed in minimum 102 mm diameter concrete encased PVC or DB2 ducts
- Tunnel supply feeders to 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 [2] requirements, or RTRC. Installations in cable trays must ensure cables are spaced to maximize cooling
For more specific information regarding TPS duct bank and conduit requirements, refer to Chapter 11, Electrical.

6.5 OVERHEAD TRACTION POWER SYSTEM

The Overhead Traction Power System (OTPS) distributes DC power from substations 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.

6.5.1.1 Overhead Contact System

The OCS consists of conductors, including contact wire and 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 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. Where the OCS has electrical support challenges, additional cable or wire has been installed overhead or underground, although additional overhead wires are not preferred for new extensions. Current return circuit is through the rails.

A Simple Catenary Auto Tension (SCAT) arrangement is used in open corridors with 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 is to be determined by the Designer of the OCS 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.

6.5.1.2 Support Subsystem

The support subsystem consists of all infrastructure required to keep the OCS in position above the track. This includes foundations, poles, guys, 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.

6.5.2 Design Philosophy

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

6.5.3 Design Requirements and Criteria

All applicable requirements from Codes, Standards and Guidelines outlined in this chapter must be considered in the Design. Summaries of design requirements are presented in the following sections.
6.5.3.1 Overhead Contact System Design Operating Speed

Speed criteria to be used in the design of the OCS are provided in Table 6.2.

**Table 6.2 OCS Mainline and Maintenance Facility Design Operating Speeds**

<table>
<thead>
<tr>
<th>Mainline</th>
<th>Maintenance and Storage Yard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum OCS design speed</td>
<td>90 km/h</td>
</tr>
<tr>
<td>Maximum LRT design speed</td>
<td></td>
</tr>
<tr>
<td>Maximum LRT operating speed</td>
<td>80 km/h</td>
</tr>
<tr>
<td>Maximum LRT operating speed</td>
<td>70 km/h</td>
</tr>
<tr>
<td>Maximum design speed</td>
<td>30 km/h</td>
</tr>
<tr>
<td>Normal yard operating speed</td>
<td>10 km/h (test track is 40 km/h)</td>
</tr>
</tbody>
</table>

**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 allowed 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.

6.5.3.2 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.

6.5.3.3 Operating Wind Speed

The OCS system must be designed for normal operation in wind speeds of 95 km/h and pressure of 450 N/m² 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].

6.5.3.4 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 informational use 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.

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2 OCS speed criteria differs from speeds stated in Chapters 2, 4 and 5 for LRV and Work Train speed criteria. 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

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

The general operational characteristics for the SD-160 LRV pantographs are listed in Table 6.4.

Table 6.4 Siemens SD-160 LRV Pantograph Operating Parameters

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

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 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.

6.5.3.5 Conductor Characteristics
Contact wire must be a grooved alloy 80 as per ASTM B9 [11] and B105 [12]. 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 ASTM B8 [13] and ASTM B1 [14] 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.

6.5.3.6 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) [15] and Overhead Systems [10], using limit state design. Provisions in CHBDC [15] are applicable to OCS structures (poles, foundations, anchors) unless otherwise accepted by the Engineer.
Structural components including contact wires, feeder wires, poles, foundations, span wires, support arms, and all associated fittings and connections must be designed for strength including standard storm 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 due to gravity 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 [15]. 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.

**6.5.3.7 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 40% wear limit based on the CSA22.3 No. 1-15 [10] recommendation that wire replacement occur at 60% of the original rated tensile strength.

The OCS Designer must ensure that the minimum contact wire thickness is identified and 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 40% of the new wire depth

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.

6.5.3.8 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.

6.5.3.9 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 take into account the system voltage level while meeting the requirements outlined in CSA C22.3 No. 1 [10]. Contact wires must be installed within the standard maximum and minimum nominal heights shown in Table 6.5. If special circumstances require contact wire to be outside of this range, the Engineer must be consulted as speed restrictions may be necessary.

<table>
<thead>
<tr>
<th>Table 6.5 OCS Contact Wire Operating Heights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Wire Height</td>
</tr>
<tr>
<td>Absolute Minimum</td>
</tr>
<tr>
<td>At-Grade and Elevated Minimum</td>
</tr>
<tr>
<td>Minimum at Road Crossings</td>
</tr>
<tr>
<td>Maximum Nominal</td>
</tr>
</tbody>
</table>

6.5.3.10 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 possible, 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 [16] 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>
<thead>
<tr>
<th>Table 6.6 OCS Contact Wire Gradient and Speed Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Yard (10 km/h)</td>
</tr>
<tr>
<td>50 km/h</td>
</tr>
<tr>
<td>75 km/h</td>
</tr>
<tr>
<td>90 km/h</td>
</tr>
</tbody>
</table>
6.5.3.11 Clearances

**Electrical Clearances**
Electrical clearances must meet CSA C22.3 No. 1 and C22.3 No. 8 requirements and should satisfy the operational limits of the LRVs and related maintenance equipment. Any other standards or codes applied by the Designer must be reviewed by the Engineer. Where clearances recommended herein differ from minimum requirements of the current codes, the higher values must govern. Refer to the applicable figures in Chapter 3, Clearances and Right-of-Way for the clearance requirements discussed below 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>
<thead>
<tr>
<th>Standard Clearanc...</th>
<th>Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Wire to Tunnel Overhead Structure</td>
<td>400 mm</td>
<td>300 mm</td>
</tr>
<tr>
<td>Feeder Wire to Tunnel Structure</td>
<td>100 mm</td>
<td>N/A</td>
</tr>
<tr>
<td>Any OCS Wire to Any Installed Hardware</td>
<td>500 mm</td>
<td>400 mm</td>
</tr>
</tbody>
</table>

**Catwalk, Stairway, and Readily Accessible Area Clearances**
Walkways, Catwalks and stairways must be kept at a safe distance from the OCS as shown in Table 6.8. Examples of areas in proximity to the overhead wires that are subject to these clearance rules are:

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

<table>
<thead>
<tr>
<th>Clearance Parameter</th>
<th>Clearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>1500 mm</td>
</tr>
<tr>
<td>Vertical</td>
<td>3100 mm</td>
</tr>
<tr>
<td>Vertical distance above</td>
<td>1500 mm</td>
</tr>
</tbody>
</table>

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 the Platform edge.

**Mechanical Clearances**
The following rules for mechanical clearances must be maintained.
OCS support locations are fixed and are entirely dependent on track alignment.

A large number of mounting brackets are required. This is a consideration for locating civil, architectural, and mechanical equipment particularly in tunnels and Stations.

Space above the LRVs 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**

The following restrictions for equipment must be maintained:

- 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 provide adequate safety to ETS personnel and avoid the need for de-energization
- If non-TP equipment has been 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**

The following restrictions for underground installations apply:

- Minimum clearances between OCS poles and anchor foundations and underground utilities must comply with CSA C22.3 No. 7 [17] and the Alberta Electrical Utility Code [18].
- Chapter 17, Utilities and Drainage also identifies minimum clearances of utilities to edge of 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 6.9. Where there is a difference between these guidelines and the code, the greater clearance must govern.

<table>
<thead>
<tr>
<th>Object</th>
<th>Clearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Mains and Water Service lines</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Gas Lines and services</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Underground Power Cables</td>
<td>1.0 m</td>
</tr>
<tr>
<td>Underground Communication Cables</td>
<td>1.0 m</td>
</tr>
</tbody>
</table>

If minimum clearances cannot be met, the Designer must coordinate clearances with the utility agency early in the design.

**Pole Clearances – Tangent Track**

The minimum clearance from centreline of track to face of pole must be 2070 mm⁴, while the minimum clearance to balance weights on pole in swing position must be 1995 mm.

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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 is preferred to promote safe refuge for maintenance personnel, space permitting. See Chapter 3, Clearances and Right-of-Way for reference figures.
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 cant from track superelevation, as outlined in Chapter 3, Clearances and Right-of-Way.

6.5.4 Details of Overhead Contact System
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 overhead contact wire system must be avoided.

When a pantograph travels along the contact wire, it deflects the contact wire upward. Traveling pantographs produce a standing wave front that precedes the current collectors. If the standing wave front encounters a “hard spot” or vertically rigid suspension point, it will reflect back towards the pantograph causing vertical wire oscillations and loss of contact in the form of vibrations and arcing, which results in accelerated wear and deterioration of both the carbon current collector and contact wire.

The messenger wire is designed as a simple catenary 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 of specified minimum intervals.

In tunnel areas, messenger wire is 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 in order to provide an elastic suspension.

6.5.4.1 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 tunnel LRT Systems.

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. The same amount of tension throughout its tension length is maintained using Balance Weight Assemblies (BWA) or spring tensioners. 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 Trackway use – 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 tunnel use – 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

In addition to the above, the design tensile strength of both messenger and contact wires must not exceed 50% of the rated ultimate tensile strength.

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 as described below.

Variable Tensioning Systems (Fixed Tension System)
This system differs from the SCAT system in that it allows wire to change its tension as a result of temperature variation. It is an acceptable method of construction in long tunnel applications with narrow ambient temperature range and short contact wire spans. It is not recommended for open Trackways and its use should be limited to areas where autotensioning is not possible and environmental conditions minimize wire tension changes.

Another fixed tension system involves adding a second messenger wire to the normal SCAT design to provide improved power and voltage support. This second messenger wire is attached on the OCS poles and is typically fixed tensioned.

6.5.4.2 Wire Tension
The Designer must consider the following factors when establishing the wire tensioning system to be used and the related 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

6.5.4.3 Wire Tensioning Equipment
The wire tensioning system must be designed to the electrical design loading identified in the Load Flow Study. The system can consist of either BWA or spring tension equipment, as specified by the Designer 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 BWA is a mechanism that maintains constant tension on the OCS wires while accommodating wire expansion/contraction due to temperature fluctuations. The current standard balance weight tensioning equipment is a tension wheel assembly that uses different diameter drums to produce a 3:1 mechanical advantage. Other possible arrangements use pulleys to achieve the 3:1 mechanical advantage. The balance weight required is 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 outlined in Chapter 1, General and must have weather and corrosion resistant properties. Balance weights must be mounted on the exterior of the pole for normal installations on dedicated LRT ROW. An exterior mounted weight stack must be designed to ensure mechanical clearances are met during all operating
conditions and provide a guide path for weight movement. In areas where OCS poles are readily accessible by the public, or an important design consideration is achieving an acceptable level of SUI, as outlined in Chapter 14, Urban Integration, the balance weights must be hidden and protected from access.

The Designer must ensure that BWA setting information encompassing all operating, installation and maintenance conditions is provided 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.

### 6.5.4.4 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. Each MPA must be installed within one span of the actual mid-point of the tension section. On open Trackways, the mid-point cantilever arm must receive its anchorage where the messenger wire attaches to it. In tunnels, the MPA must be anchored to the tunnel ceiling.

### 6.5.4.5 Terminations or Dead Ends

OCS wires can be terminated or dead ended on freestanding or anchored poles, retaining walls, buildings, ceilings, or bridge structures. There are two types of terminations:

- Fixed termination\(^5\) – where the wires are attached directly onto supporting structures via a two-level insulator assembly
- Constant tension termination – where the wires are connected to an auto tensioning device, also known as an auto tension termination

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. Consideration should be given to avoiding functional interference with servicing equipment used for maintenance purposes. Turnbuckles must be installed on the structure side of the line insulator.

Dead end and associated structures at end of line are to be located with consideration of future expansion. These structures should not conflict with the future track’s Vehicle Running Clearance Envelope (VRCE).

### 6.5.5 Overhead Contact System Configurations

#### 6.5.5.1 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

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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.
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 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 and electrically independent from each other and from subsidiary tracks and sidings.

**6.5.5.2 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 [16]). The following limiting factors should be considered:

- 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
- Radial loads on structures
- Cost considerations based on structure and foundation sizing, quantity and labour effort for supporting structures on tangent line.

In general, the maximum simple catenary spans allowed are 55 m and 58 m. For tunnel construction, the maximum spacing between elastic supports is 11 m.

**6.5.5.3 System Depth**

System depth is defined as the separation between messenger and contact wires at the point of support. The nominal system depth is 900 mm with 4/0 messenger wire and 1600 mm with 500 kcmil messenger wire.

For design of future LRT extensions, the nominal system depth must be determined by the Designer considering wire size, wire tensions, span length, dropper lengths and minimum separation of 150 mm between contact and messenger wires at mid-span. Depth should be optimized based on economic and technical criteria.

**6.5.5.4 Contact Wire Stagger**

To avoid overheating and ensure uniform wear of the LRV’s pantograph, the contact wire is continuously staggered from pantograph centreline. Stagger should be specified to be as wide as possible while remaining on the operating width of the pantograph’s carbon current collector and allowing for permissible displacement.
Sections of unstaggered wire are permitted at overlap transition spans. The length of unstaggered wire must not exceed 12 m and should not be in an acceleration zone.

Range of stagger must be confirmed through pantograph security analysis conducted by the Designer considering dynamic horizontal movement of the pantograph. This must identify maximum stagger values in tangent and curve 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 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 are required for contact wire heights in excess of 5.5 m. The nominal contact wire stagger must not be less than 100 mm. Installation tolerances of contact wire stagger must not exceed ±10 mm.

6.5.5.5 Contact Wire Dynamic Displacement
In addition to stagger, the contact wire will experience dynamic displacement from its static position at mean temperature. The effects described below contribute to contact wire displacement.

Wind Blow-off and Stagger Effect
Wind blow-off is defined as the lateral displacement of a contact wire between supports caused by wind pressure acting on the messenger wire, contact wire, and dropper wires in combination without ice accretion. This displacement is maximum at midspan, and zero at the steady arm support. Stagger effect is the portion of wind deflection of contact wire beyond the design stagger measured horizontally from the support point. Stagger effect occurs between the support and mid-span for staggered wires. For unstaggered wire, the stagger effect occurs at mid-span and is equal to blow-off. The larger the design stagger the less the stagger effect.

Stagger Change (Δ-Stagger)
Stagger change is defined as the increase in wire stagger (Δ-stagger) produced by rotation of the contact wire support cantilevers due to thermal expansion and contraction of the catenary and contact wires in auto tensioned systems. Stagger change is proportional to the support cantilever length and is greater for shorter contact wire support cantilevers. Maximum stagger change occurs at the last support arm located within the overlap transition span before a tensioning assembly.

Pole Deflection
Under transverse wind loading, the OCS support pole will experience elastic deflection resulting in a vertical rotation of the catenary support arm assembly and a subsequent transverse displacement of the contact wire. The direction of wind and subsequent pole deflection must be assumed to occur in any direction.

The OCS Design must include a pantograph security analysis to ensure that contact is maintained between the contact wire and pantograph carbon strip. Displacement of the contact wire from centreline of the pantograph must not exceed half the width of the pantograph carbon strip, including stagger, wind blow-off, stagger effect, Δ-stagger, and pantograph sway due to vehicle dynamics, track tolerances, and pantograph flexure.

6.5.5.6 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 occur, a separate tension length is required 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.

Overlap arrangement 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. A 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 are required 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 main line tension section. Section isolators located in crossover movements must provide adequate clearance from the track diamond crossing point in order to achieve adequate clearance from the crossing pantograph. Transition span poles must be accurately located adjacent to the track switch frog in order to achieve the correct alignment across the crossover. OCS support poles must be set back from the divergent track, ensuring enough clearance envelope to the DVDE.

6.5.6 Overhead Contact System Support Components

As the LRT is extended into a more urban setting adjacent to established residential communities, the Designer must recognize the need to blend and integrate OCS support components to achieve an acceptable level of SUI as outlined in Chapter 14, Urban Integration, while considering the corridor type as outlined in Chapter 1, General. The objective to make OCS supports as unobtrusive as possible may become an important design consideration requiring increased coordination with the Engineer.

An overview of the general design guidelines for a variety of components that are required to support the OCS is 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 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.

6.5.6.1 Poles

New construction must use straight octagonal shaped poles to support an OCS on the existing LRT System. Because corrosion due to road salt and condensation is highly problematic, 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. Normally poles are not painted or powder coated, however, if a pole is to be painted or powder coated the coating system must comply with the City of Edmonton Design and Construction Standards and more specifically the Road and Walkway Lighting Construction and Material Standards.

In some instances, signage and/or lighting of the LRT corridor or surrounding area may require shared use poles. The requirement for shared use poles is dependent upon the level of SUI required, the land available for the LRT ROW, and the planned delineation between the LRT and surrounding Streets.
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 Designer must coordinate the pole design with the Engineer and other Owner stakeholders to ensure appropriate integration is achieved between the TPS and other systems using the pole.

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. The number of different pole designs must be limited by practical considerations for simplicity and flexibility in application.

**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. In addition, poles are required to support these loads without yielding, fracturing, or shearing. Effects of Euler buckling must also be considered in the design. 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.

**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 cantilever 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 [19], and CAN/CSA-G40.20 [20] or an approved equivalent.
In order to reduce maintenance costs and maximize the life of the system, for new construction OCS poles must be galvanized as per CSA G164 [21] with a minimum coating density of 610 g/m³.

Special architectural requirements may require that OCS poles be galvanized and painted or powder coated.

**Standard Pole Details**

For new construction, nominal pole heights must be equal, where practical, for uniformity of sizing.

Standard cantilever poles must be octagonal in cross-section and non-tapered to accommodate attachment of standard cantilever arms and balance weight 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 designed with adequate reinforcement to ensure that there is no reduction in flexural capacity of the shaft at the opening locations.

If a pole with internal balance weights is required, it must be constructed with adequately sized openings to house and mount the BWA and an inspection/adjustment access panel. These openings must be designed with adequate reinforcement to ensure there is no 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 practical. The pole must be designed to be directly bearing 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**

Standard 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 prior to the foundation design. Poles may be mounted on bridge decks or structurally reinforced slabs upon approval of the Engineer. Pole bases must have provision to level the poles and must provide a drainage port for any water buildup inside the poles.

Standard LRT 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 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 pattern⁶.

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⁶ The Designer of the pole foundation must coordinate with the Designer of the OCS pole early in the design to ensure that the foundation, pole to foundation fastening devices, and poles are properly interfaced.
Overhead Contact System Pole Anchors
Pole anchors are used to provide additional resistance to bending for poles that support longitudinal loads from wire ends and wire tensioning equipment. Preference is to not use pole anchors if possible. If used, the pole anchors must be designed to support design loads without yielding, fracturing or shearing.

Pole anchors must not be installed in any location that will expose them to the risk of damage from vehicles or equipment. If anchors must be installed in such an area, concrete filled steel bollards must be installed to protect the anchor from impact. Protective bollards must be tall enough to be visible and must be painted a bright contrasting colour.

Overhead Contact System Pole Identification
Every pole must be labelled with a unique identifier as per the Operator’s existing labeling format. Identifier labels must be reflective and must be visible to the Train Operator (TO) in normal operating direction. Center mounted poles must have a label on both sides.

6.5.6.2 Cantilever Arm Assemblies
For a typical simple catenary configuration, cantilever arms are clamped to poles and are used to carry the OCS wires. There are several types of standard cantilever arms. The type to be used is dependent upon the application, and each must be suitable for the design loading it will encounter.

In its static position, the contact wire steady arm must be sloped downwards a minimum of 4° from horizontal and must pivot at the arm strut connection to allow differential movement of contact wire and catenary messenger wire.

The contact wire registration 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 preferably 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 application of standard cantilever arms and for designing any non-standard cantilever arms as required.

6.5.6.3 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 are attached to the tunnel structure with rigid steel brackets configured for the particular tunnel geometry, or mounted directly to the structure. All tunnel arms 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 format.

Overhead Conductor Rail
Overhead conductor rail is an alternative tunnel support system. This typically consists of a rigid aluminum section clamped onto the contact wire with application of a conductive grease. It 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 before design of a conductor rail system is started.

### 6.5.6.4 Span Wire Suspensions

Overhead contact (energized) wires 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 are used to support pull-offs through small radius curves.

In tunnel applications, span wire is typically anchored to tunnel walls and suspended from the tunnel ceiling with dropper wires. A steady arm is suspended from the span wire to elastically support the contact wire. In general, contact wires must not be rigidly attached to span wire supports. Messenger wire is typically 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.

### 6.5.6.5 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 outlined in Chapter 9, Structures.

### Design Considerations

The following considerations must be accounted for in the Design:

- Care should be taken to isolate any electrified components from any structures or supports
- All attachment wires must have at least two levels of insulation
- Any conductors attached to the roof of a structure must be mounted opposite an Emergency Egress Walkway
- A non-conducting material such as plastic sheeting must be considered for installation between the underside of a bridge deck and the LRT energized wires
- 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 [16] and CSA C22.3 No. 1 [10] pursuant to the Alberta Electrical Utility Code [18]
- All exposed metal must be securely grounded
- Provision for protective screening where pedestrians or Patrons are 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 and Trains from damage and to protect the public from accidental contact with an energized wire. A minimum 3 m limit of approach for pedestrians or Patrons 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. Screens should be painted to match the color of the building or bridge structure to blend in with the surrounding environment.
6.5.6.6 Vibrations & Special Connection Details
Due to the vibration associated with LRT operations, the Designer must specify appropriate non-permanent thread locking compounds to be used for all threaded fastenings. Lock washers and nuts must be specified where appropriate.

Where necessary, effects of vibration fatigue must be considered in design of LRT components and concrete anchorages.

6.5.6.7 Concrete Anchors
Fittings and assemblies requiring mounting to concrete structures must be fastened with specially designed anchors cast into the concrete or with Hilti concrete anchors (or approved equivalent).

All concrete anchorages must be sized and detailed for adequate strength and durability. Combined effects of shear, tension, and bending must be considered when calculating anchorage capacity. Concrete anchors must be designed and installed in compliance with the anchor manufacturer’s recommended practice.

Anchors must be conservatively designed in order to account for concrete surface irregularities and potential variances in the base concrete strength and quality.

Anchorages must have adequate corrosion resistance; materials such as zinc plated carbon steel or stainless steel provide adequate resistance. In wet or corrosive environments stainless steel is preferred and additional anchors must be specified to provide long-term durability and an increased factor of safety.

For lighter load applications, Hilti Kwik Bolt anchors (or equivalent) must be used. For heavy duty applications, Hilti HSL anchors (or equivalent) must be used. Anchorages requiring epoxy compounds or cements should only be used upon approval of the Engineer.

6.5.6.8 Standard Small Parts Steel Work
Where practical and economical, standard fittings and attachments must be specified by the Designer and fabricated locally.

Locally fabricated small parts constructed of steel must generally conform to the Design and be able to support identified design loads. Material composition, manufacturing, galvanization, and welding design and workmanship must be in accordance with the latest applicable CSA standards. Specific requirements are to be clearly identified by the Designer.

The Designer must also coordinate with the Engineer to identify specific requirements for ultrasonic and magnetic particle testing employed on structural welds.

6.5.7 In-Span Assemblies
In-span assemblies are additional devices that are required to make the OCS functional. They include major components described below.

6.5.7.1 Dropper Wires
Dropper wires, or hangers, are used to suspend contact wire from catenary messenger wire in a flat profile. The Designer must determine dropper spacing to ensure the contact wire is supported evenly throughout each span. Dropper wires must be isolated so that they do not create a conductive path between the contact and messenger wires. Dropers adjacent to supports must be located such that they do not contribute to creation of a hard spot.
**6.5.7.2  Equalizing Jumpers**

The OCS is electrically fed from a messenger wire. Equalizing jumpers, also known as in-span jumpers or catenary Bonds, connect the contact wire and messenger wire at a standard spacing along the alignment as determined by the OCS Designer. Their primary purpose is to ensure that ampacity, voltage drop, and wire heating are all within design limits.

The Design must ensure the following requirements are met:

- A sufficient number of jumpers are provided to satisfy system electrical requirements
- Jumpers are 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
- Minimum jumper size must be 336 strand 4/0 bare copper
- Jumpers must not be installed at locations near section isolators or splices

**6.5.7.3  Parallel Feeder Bonds**

In some locations, a parallel feeder cable or parallel messenger wire is installed along the track alignment separate from contact or catenary wires. Also called feeder taps, parallel feeder bonds must be installed at appropriate intervals to ensure ampacity, voltage drop, and wire heating is within design limits. Maximum spacing is to be determined by the OCS Designer. Parallel feeder bonds must be designed as follows:

- Stranded copper, with ampacity as Design
- Insulation level must be minimum 2 kV AC/2.5 kV DC XLPE
- PVC conduit or cable coverings must not be used in tunnel applications
- Parallel bonding cable requirements must follow DC feeder bonding requirements for tunnel applications

The OCS Designer must specify the ampacity of feeder bonds but in no case may they be less than the ampacity of parallel feeder cable or parallel messenger wire.

**6.5.7.4  Feeders**

Feeders provide a connection point for DC power supply between PDS and OCS. The OCS Designer must coordinate with the TPSS Designer for location of feeders. To limit cable lengths, feeders must be located as close as possible to a TPSS.

Where practical, feeders must be located close to Stations, which is desirable to limit voltage drop and wire heating near acceleration zones.

NCFs are coordinated with the Signal System Designer for connection to rail. This is typically done at the centre tap of an impedance Bond.

**6.5.7.5  Electrical Switches**

Each substation is accompanied by Feeder Switches (one for each circuit) that provide a disconnect point between the substation and the OCS. Tie Switches are included and are used to connect two adjacent OCS circuits together. These switches are normally open and are typically used to bypass a substation during a feeder outage. Feeder and Tie Switches should be housed in fibreglass enclosures within or directly adjacent to the exterior of a substation.

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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. Contact wire wear is also a factor at these hard spots.
Where Tie Switches are required to connect two adjacent portions of a single OCS circuit, pole mounted switches should be used. These sectionalizing switches are normally closed to improve operational flexibility and should only be used in special circumstances, such as crossovers or additional sectionalizing. OMF locations also typically have a requirement for additional pole or wall mounted switches to improve flexibility of maintenance activities.

Any pole or wall mounted electrical switches must be designed to be hand operated with a remote mechanical handle accessible from ground level that is adequately bonded and grounded. Switches and their operating handles must be designed to withstand mechanical forces necessary to operate in low temperatures.

All electrical switches must be installed with adequate signage indicating their identification number, matching the LRT DC circuit schematics. Switch numbering must be coordinated with the local power utility control authority.

### 6.5.7.6 Section Isolators

Where two adjoining positive overhead contact wire circuits meet, a section isolator is used to electrically separate them 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 substation maintenance.

Section isolators must not be installed in an LRV acceleration zone to ensure that power is constantly provided to the LRV during its acceleration period.

Section isolators must be suitable for maximum operating Train speed in both directions. They must be designed and located such that there must be no loss of contact with the pantograph to affect Train operation. Section isolators must be installed as close as possible to the pantograph static centreline.

On open Trackway, section isolators are to be suspended from catenary messenger wire with dropper wires. In box tunnels and underground Stations, section isolators are to be suspended with dropper wires and brackets that accommodate movement of the component due to contact wire thermal expansion and contraction.

### 6.5.7.7 Splices

A splice is a mechanical device used to connect two wires together. 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 electrical ampacity rating equal to or greater than the conductor, and mechanical strength equal to or higher than the wire being spliced.

### 6.5.7.8 Conductors and Related Devices

The OCS Designer must ensure 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.

### 6.5.7.9 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 substation equipment. Ratings of surge arrestors must be coordinated with substation surge protection with a minimum short circuit capacity specified by the TPSS Designer.
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 are required at the following 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

Tracks must not be bonded to the surge protection ground. All lightning arrestors installed in the LRT ROW must be complete with a surge counter mounted at eye level.

6.5.7.10 Structure Grounding and Bonding

The LRT TP electrical system is an ungrounded (floating) system except for OMFs where a portion, or all of the tracks are grounded.

In general, grounding is required for the following elements:

- All conducting structures within the LRT System
- OCS mounting hardware
- All utilities encased in metal conduit in tunnels

A 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. In tunnel applications, a continuous OCS bonding conductor must be provided for grounding all OCS hardware.

All structures within 2 m of an OCS structure must be bonded together and not connected to a lightning arrester ground.

6.5.7.11 Protective Grounds

Protective Ground points, also referred to as temporary grounds are used for grounding the OCS wires during maintenance or repairs. Protective Grounds are located at points where energy can be introduced to the system. The 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 currents to ground.

6.6 TESTING AND COMMISSIONING

Testing and commissioning of the TP system must be carried out in accordance with an overall commissioning plan and program (refer to Chapter 1, General).
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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 UTILITY COMPLEX YARD.
4. LOCATION OF UTILITY STATION SERVICE TRANSFORMER, SWITCH CUBICLE, AND MAHNOLES ARE TYPICAL AND FOR INFORMATION ONLY.

FIGURE 6.1A
TYPICAL UTILITY COMPLEX BUILDING LAYOUT

Date  Revision
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CITY OF EDMONTON – LRT DESIGN GUIDELINES

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FIGURE 6.2B
TYPICAL OSMF TPSS SINGLE LINE DIAGRAM

Date  Revision
LEGEND
- BUILDING REBAR GROUND CONNECTION
- GROUND TAIL EQUIPMENT GROUNDING
- GROUND ROOD
= 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.

FIGURE 6.3A
TYPICAL UTILITY COMPLEX
GROUND GRID LAYOUT
FIGURE 6.4
TYPICAL OCS
SIMPLE CATENARY LAYOUT

MAST

CONTACT WIRE

CANTILEVER ARM

CATEGARY ON ONE SIDE OF MAST

CATEGARY ON BOTH SIDES OF MAST

SIMPLE CATEGARY SPAN

PARALLEL MESSANGER (WHERE NECESSARY)

DROPPER WIRE

PARALLEL MESSANGER (WHERE APPLICABLE)

CONTACT WIRE

CATEGARY BOND

FOUNDATION

DIRECTION OF TRAVEL

PARALLEL MESSANGER (WHERE NECESSARY)

MESSANGER WIRE

CATEGARY ON ONE SIDE OF MAST

CATEGARY ON BOTH SIDES OF MAST
FIGURE 6.7
TYPICAL CATEenary
WIRE PROTECTION
BRIDGE / PORTAL STRUCTURE

NOTES:
1. SHROUD TO PROVIDE PROTECTION FOR ALL CATEenary.
2. CONFIGURATION MAY VARY.
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 UTILITY COMPLEX YARD.
4. LOCATION OF UTILITY STATION SERVICE TRANSFORMER, SWITCH CUBICLE, AND MANHOLES ARE TYPICAL AND FOR INFORMATION ONLY.

FIGURE 6.1A
TYPICAL UTILITY COMPLEX BUILDING LAYOUT

CHAPTER 6 | TRACTION POWER
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 UTILITY COMPLEX YARD
4. LOCATION OF UTILITY STATION SERVICE TRANSFORMER, SWITCH CUBICLE, AND MANHOLE ARE TYPICAL AND FOR INFORMATION ONLY

FIGURE 6.1B
TYPICAL OMSF TPSS BUILDING EQUIPMENT LAYOUT

CHAPTER 6
TRACTION POWER

Date  Revision
LEGEND:
- BUILDING REBAR GROUND CONNECTION
- GROUND TAIL EQUIPMENT GROUNDING
- GROUND ROOD
- 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.

FIGURE 6.3A
TYPICAL UTILITY COMPLEX GROUND GRID LAYOUT

Date
Revision
LEGEND

- Building Rebar Ground Connection
- Ground Tail Equipment Grounding
- Ground Rod
- 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.

FIGURE 6.36
TYPICAL OMSF TPSS BUILDING GROUND GRID LAYOUT
FIGURE 6.7
TYPICAL CATENARY WIRE PROTECTION
BRIDGE / PORTAL STRUCTURE

NOTES:
1. SHROUD TO PROVIDE PROTECTION FOR ALL CATENARY,
2. CONFIGURATION MAY VARY.
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Signals
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7.0 SIGNALS

7.1 INTRODUCTION

This chapter provides the guidelines and general requirements for the design of modifications and extensions for Signals on the 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) [1]
- Transport Canada Grade Crossing Standards [5]
- 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

A Signal System is not mandatory on a railway to govern Train operations. Railway Signal Systems primarily serve to enhance a railway’s efficiency by allowing Trains to operate more quickly and frequently by providing an engineered solution to increasing risks that emerge from quicker and more frequent Trains. Signal Systems also help mitigate risks in other areas such as public crossings At-Grade and Right-of-Way (ROW) integrity detection. The inherent risks associated with operating a railroad at heightened performance demands that a Signal System be designed to fail safely and in many cases to prevent human error.

All Signal Systems that govern Train movements, fundamentally ensure that Trains remain a safe distance apart. As operations increase in complexity and frequency, so does the necessity for complexity of the Signal System.

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
CITY OF EDMONTON – LRT DESIGN GUIDELINES

- 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 intervention 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)s.

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 below.

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum Operational Headway (minutes)</th>
<th>Design Headway (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>All</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Nearest Interlocking to Terminus (including a turnback)</td>
<td>All</td>
<td>3</td>
</tr>
</tbody>
</table>

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 ensures the overall system response provides adequate 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 following operational risks presented in Table 7.2 below.
Table 7.1 Signal System Mitigation of Typical Operational Risks based on Train Priority

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>Operating Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full Priority – Traditional Signaling</td>
</tr>
<tr>
<td>Following Move Collision</td>
<td>Yes</td>
</tr>
<tr>
<td>Opposing Move Collision</td>
<td>Yes</td>
</tr>
<tr>
<td>Conflicting Move Collision</td>
<td>Yes</td>
</tr>
<tr>
<td>Vehicular Collision</td>
<td>Provide Warning</td>
</tr>
<tr>
<td>Pedestrian/Cyclist Collision</td>
<td>Provide Warning</td>
</tr>
<tr>
<td>Over-Speed Derailment or Injury</td>
<td>Yes</td>
</tr>
</tbody>
</table>

7.4.1.4 Operating Assumptions and Principles

Operation of the Signal System requires that ETS personnel are compliant 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 implementing 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 specifications must be developed for major components that have not been previously used on the LRT System. The Designer must ensure that Reliability, Availability and Maintainability (RAM) are specified in accordance with industry expectations. When required by the Engineer, a Systems Assurance Plan should 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 should be developed based on the Systems Assurance Guideline and consider 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 $1 \times 10^9$ Train operating hours for Train-borne equipment and fewer than 1 unsafe event for every $1 \times 10^9$ 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 should 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 must ensure that 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. No latent failure may result in an unsafe condition when combined with any other failure. Failure modes that cannot be removed from a system through engineering mitigations must result in prescribed periodic testing of the affected subsystems to ensure that failures are detected 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: 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 will 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, stating that the probability of any failure or combinations of failures in a system that 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 utilize a form of check-redundancy principal 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 is inherently Failsafe
- The checking process is sufficiently frequent that similar or identical errors or failures in redundant units could not occur between checks
- The checking process is sufficiently sensitive to detect significant errors in a single unit
- Failure to check causes timely action to occur which maintains safety
Redundant units are 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 cannot 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 (ACBs)

##### 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 utilized.

**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 requires 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 be adequate to allow the Signal System to initiate unsafe events. This feature must be used in conjunction with Sequential Track Circuit Clearing 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 employed 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) ensures that human error cannot lead 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 ensure Trains are brought 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-stops 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 Error! Reference source not found. 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 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 are 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 (SERs) 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 the other SERs.

The existing SER locations and the territory are shown in Table 7.2 below:

<table>
<thead>
<tr>
<th>SER</th>
<th>Signal Territory</th>
<th>Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belvedere (BEL)</td>
<td>Clareview to 66 Street</td>
<td>Capital</td>
</tr>
<tr>
<td>Coliseum (COL)</td>
<td>66 Street to Stadium</td>
<td>Capital</td>
</tr>
<tr>
<td>Churchill (CHU)</td>
<td>Stadium to Central and North from Churchill to MacEwan</td>
<td>Capital (Metro shared)</td>
</tr>
<tr>
<td>Corona (COR)</td>
<td>Central to North Portal</td>
<td>Capital (Metro shared)</td>
</tr>
<tr>
<td>University (UNI)</td>
<td>North Portal to McKernan/Belgravia</td>
<td>Capital (Metro shared)</td>
</tr>
<tr>
<td>South Campus (SC)</td>
<td>McKernan/Belgravia to South of 60 Avenue BS734</td>
<td>Capital</td>
</tr>
<tr>
<td>Southgate (SGT)</td>
<td>South of 60 Avenue BS736 to North of 34 Avenue BS1078</td>
<td>Capital</td>
</tr>
<tr>
<td>Century Park (CPK)</td>
<td>North of 34 Avenue to Century Park</td>
<td>Capital</td>
</tr>
<tr>
<td>Kingsway (KNG)</td>
<td>North of MacEwan to NAIT</td>
<td>Metro</td>
</tr>
</tbody>
</table>

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

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>
<thead>
<tr>
<th>Aspect</th>
<th>Indication</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Clear</td>
<td>Proceed</td>
</tr>
<tr>
<td>FG</td>
<td>Clear, Traffic Fault</td>
<td>Proceed, approaching crossing with caution</td>
</tr>
<tr>
<td>G/L</td>
<td>Divergent Route, Clear</td>
<td>Proceed, slowing to prescribed speed through turnouts</td>
</tr>
<tr>
<td>FG/L</td>
<td>Divergent Route, Clear, Traffic Fault</td>
<td>Proceed, slowing to prescribed speed through turnouts and approaching crossing with caution</td>
</tr>
<tr>
<td>Y</td>
<td>Crossing Not Activated</td>
<td>Authority is valid, crossing ahead not yet activated</td>
</tr>
<tr>
<td>Y/L</td>
<td>Diverging Route, Crossing Not Activated</td>
<td>Authority for divergent route is valid, crossing ahead not yet activated</td>
</tr>
<tr>
<td>R/FY</td>
<td>Prepare to Depart</td>
<td>Lock doors and prepare to depart. Permissive aspect will be displayed shortly</td>
</tr>
<tr>
<td>R/Y</td>
<td>Hold in Station</td>
<td>Traffic Signal System requires additional time. Train held</td>
</tr>
<tr>
<td>FR</td>
<td>Restricting</td>
<td>Proceed at restricted speed</td>
</tr>
<tr>
<td>R</td>
<td>Stop</td>
<td>Stop</td>
</tr>
</tbody>
</table>
### Table 7.4 Call-On Signal Aspects and Indications

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Indication</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Crossing Activated.</td>
<td>Crossing warning system is active</td>
</tr>
<tr>
<td>FG</td>
<td>Crossing Active, Traffic Unhealthy</td>
<td>Approach crossing with caution.</td>
</tr>
<tr>
<td>Y</td>
<td>Crossing Not Activated</td>
<td>Crossing not activated</td>
</tr>
</tbody>
</table>

### 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 7.5 Block Signal Light-Out Downgrades

<table>
<thead>
<tr>
<th>Intended Aspect</th>
<th>Lamp with Light-out Condition</th>
<th>Resulting Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>R</td>
<td>Dark</td>
</tr>
<tr>
<td>FR</td>
<td>R</td>
<td>Dark</td>
</tr>
<tr>
<td>Y</td>
<td>G</td>
<td>R</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>G</td>
<td>G</td>
<td>R</td>
</tr>
<tr>
<td>G</td>
<td>Y</td>
<td>G</td>
</tr>
<tr>
<td>G</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>Y/L</td>
<td>G</td>
<td>R</td>
</tr>
<tr>
<td>Y/L</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>Y/L</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>Y/L</td>
<td>R</td>
<td>Y/L</td>
</tr>
<tr>
<td>G/L</td>
<td>G</td>
<td>R</td>
</tr>
<tr>
<td>G/L</td>
<td>Y</td>
<td>G/L</td>
</tr>
<tr>
<td>G/L</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>G/L</td>
<td>R</td>
<td>G/L</td>
</tr>
</tbody>
</table>

### Table 7.6 Call-On Signal Light-Out Downgrades

<table>
<thead>
<tr>
<th>Intended Aspect</th>
<th>Lamp with Light-out Condition</th>
<th>Resulting Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Y</td>
<td>Dark</td>
</tr>
<tr>
<td>FG</td>
<td>Y</td>
<td>FG</td>
</tr>
<tr>
<td>FG</td>
<td>G</td>
<td>Y</td>
</tr>
<tr>
<td>G</td>
<td>G</td>
<td>Y</td>
</tr>
<tr>
<td>G</td>
<td>Y</td>
<td>G</td>
</tr>
</tbody>
</table>
### 7.6.2.4 Signal Configurations

<table>
<thead>
<tr>
<th>Signal Configuration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Block Signal (2 aspect)</strong></td>
<td>A fixed Signal at the entrance of a block/interlocking to govern Train authority. Only one aspect visible at a time.</td>
</tr>
<tr>
<td><strong>Call-On Signal (2 aspect)</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Combined Block/Call-On Signal</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Block Signal With Lunar</strong></td>
<td>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.</td>
</tr>
</tbody>
</table>
### 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 7.1 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 is to 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 will 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 Sightlines
Due to the use of a two-aspect Signal System, Trains require adequate sightlines to a Signal to ensure that the Train will be able to 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 distance 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 the operational performance.

Where an overlap contains power switches, these elements 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 effective 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.
7.7.5 Block Validation

The Designer must perform an analysis to ensure that the overall Signal Block design will support the operational requirements outlined 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 ensure that a specified maximum speed is not 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 desired speed plus an additional 5 km/h.

7.8.2.2 Placement of Speed Checks

Speed Checks Entering a Curve
Speed Checks are required 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. For curves, the Passenger comfort speed is calculated based on an unbalanced track super-elevation of 100 mm. Speed Checks should 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. As well, 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 are required 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 possible 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 block overlap beyond the Station is shorter that the design standard a Speed Check must be provided. 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 ensure appropriate Passenger comfort speed has been reached if the switch is lined for the reverse position. On installations where the crossover is in an area where the posted speed is 70 km/h, Speed Checks must be installed at two locations prior to the entrance to the crossover to allow sufficient time to slow the train at the standard deceleration rate. At locations where the posted speed is at or below 60 km/h, a single Speed Check may be adequate.

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. Speed Checks must also be used to promote a maximum speed entry into a Station regardless of the presence of adjacent At-Grade crossings.
### 7.9 STANDARD OPERATIONAL FEATURES

The LRT Signal System includes the standard operational functionality available on any Interlocking based railway Signal System. These include 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 inter-connects the Vital and Non-Vital system to allow integrated functionality
7.10.1.1 Vital System
The 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 is able to communicate 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 mitigate any controls received to ensure only safe results occur. Refer to Section Error! Reference source not found. 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 in order 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

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 enables both 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 enable 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 it is possible for the route to 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) transit yard.
and multiple user workstations located at the LRT OCC and other key office locations. VLCs in each Signal room communicate with CTC.

The equipment directly available in the LRT OCC consists of multiple consoles, each with multiple monitor workstations.

### 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 the Guidelines for 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/archival/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 LRVs, training LRVs, 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’s 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 ensure that a collision between the Train and other traffic does not occur. This is done by incorporating the measures as described below into the design and as per the Transport Canada Guidelines. Generally, there are four levels of control available for At-Grade crossings.

### 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:

- Sightlines for the public
- Sightlines 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 priority for the Train. As described in Chapter 1, General, this method of control is not permitted on the LRT System, although static signage is used in conjunction with active controls described below.

Traffic Signals
Standard traffic signals may be used to control the intersection of Trains with pedestrians, cyclists, or motor vehicles. To achieve acceptable LRT System operations, the Design should provide Signal priority to the LRT.

The level of warning, situational awareness, and system integrity provided by traffic signal control is not considered acceptable for Trains travelling at greater than 25 km/h.

Railway Crossing Warning Devices: Flashing Lights, Bells, and Gates
Typical railway crossing warning devices consisting of flashing lights and bells are 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 pre-emption of traffic signals is used where nearby intersection traffic control is provided.

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 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 visual cues of a second Train approaching.

7.13.2.4 Crossing Sightline and Safety Assessment
An assessment of sightlines 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 as evidence to 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 on total LRT pre-emption. At any At-Grade crossing of a Street, Trains have full priority and traffic signal pre-emption. Trains are not restricted or slowed to accommodate At-Grade crossing signal conflicts. To help ensure 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) [5].

7.13.3.3 Activation of Crossing Warning System
All At-Grade Crossing Warning System (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 traffic time 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
Grade crossings located near road intersections must provide an interface to the traffic signal control system. This interface must:

- Allow motor vehicle traffic queued near the crossing surface 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. This information allows coordination of Train and Street traffic movements though the intersection.

The Designer should refer to TCGCS as a guideline to determine if pre-emption time is required. The Owner will provide the final decision on traffic signal controller requirements including advance pre-emption time.

### 7.13.3.8 Stopping Distance – At-Grade Crossing
The stopping distance for an At-Grade crossing is determined based on the following assumptions:

- The Failsafe crossing warning system has failed
- The TO has failed to stop at the protecting Signal
- The trip stop magnet for the protecting Signal is fully operational
- Full dynamic braking is available
- Average retardation rate is 1.70 m/s² for level grade
- Total trip stop and equipment reaction time is 2.1 seconds.

### 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>
<thead>
<tr>
<th>AUTO</th>
<th>BYPASS</th>
<th>Crossing State for Associated Track</th>
<th>Crossing Behaviour Associated with this Knife-Switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>LOW</td>
<td>MANUAL</td>
<td>Crossing must be activated indefinitely</td>
</tr>
<tr>
<td>LOW</td>
<td>HIGH</td>
<td>BYPASS</td>
<td>Crossing must be unresponsive to approaching Trains on this track, acting as though no Trains are approaching on the track</td>
</tr>
<tr>
<td>HIGH</td>
<td>LOW</td>
<td>AUTO</td>
<td>Crossing must activate normally with Trains operating on this track</td>
</tr>
<tr>
<td>HIGH</td>
<td>HIGH</td>
<td>INVALID</td>
<td>Crossing is be activated indefinitely</td>
</tr>
</tbody>
</table>
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 earth 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 presented 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
The length of the crossing approach is calculated by the distance the Train will travel, at posted speed, in the amount of required warning time plus a system reaction time of 1 s. For example, where \( L \) is the length of the approach circuit with a posted approach speed of 50 km/h:

\[
L = \frac{50 \text{ km/h} \times 1000 \text{ m/km} \times (20 + 1) \text{ sec}}{3600 \text{ sec/h}}
\]

\( L = 292 \text{ m} \)

7.13.5.3 Timers of 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 CWI 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 7.9 Transit Signal Aspects and Indications**

<table>
<thead>
<tr>
<th>Transit Signal Aspects and Indications</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical White Bar</td>
<td>White vertical bar indicates movement through the intersection is permitted.</td>
</tr>
<tr>
<td>Flashing Vertical White Bar</td>
<td>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.</td>
</tr>
<tr>
<td>Horizontal White Bar</td>
<td>White horizontal bar indicates movement through the intersection is prohibited.</td>
</tr>
</tbody>
</table>

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.

Due to weather conditions in Edmonton, all new outdoor Wayside equipment must be rated for temperatures that meet or exceed 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 [6], and emissions of Signal equipment must conform with EN50121-4:2006 [7].

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 is 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 Designer must ensure that an adequate electrical power supply is provided as described 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 not be governed by the CEC.

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 [8].

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

7.16.4 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 employing the check-redundancy principles defined in Section Error! Reference source not found.. 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 AND JUNCTION BOXES

All bungalows and junction boxes must be corrosion and weather-proof. Bungalows and enclosures must be insulated and be equipped with Heating Ventilation Air Conditioning (HVAC), capable of venting battery gas at a safe air exchange rate. Refer to Section 11: Circuit Protection in AREMA [8] for details on the environmental limits of equipment.

All bungalows and junction boxes must be sealed to prevent access by insects and rodents.
All bungalows and junction boxes for the Wayside Signal equipment must be clear of the Design Vehicle Dynamic Envelope (DVDE) as described 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 outlined in Chapter 11, Electrical.

#### 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.

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 HARDWARE: SIGNALS

#### 7.18.1 Signal Heads
All Signal heads installed on the LRT System must be accepted for use in railway Signaling applications by a recognized international regulatory body governing the installation of railway Signal Systems.

##### 7.18.1.1 Colour Light Signals
Based on Failsafe Signal design principles, filament Signal lamps must be monitored by a cold filament check. RED or YELLOW lights must have double element incandescent lamps, the principal and the secondary element. A Signal disturbed alarm must be issued to the LRT OCC if the principal element has burned out.

All Signal lights must be complete with proper lenses and filters. The power supply for the LRT Signal lights must come directly from the SER or VLC controlling the Signal. The outgoing power must not be grounded (isolated power). Hoods on Signal lights must be provided so that glare from the sun does not interfere with the TO’s vision of the Signal. When Light Emitting Diode (LED) Signal lamps are used, light-out detection must be provided via cold filament check with status information sent to the CTC system. LED light-out alarm must be Failsafe.

##### 7.18.1.2 Dual Filaments
All incandescent red or yellow aspects must utilize a dual filament bulb or include two bulbs. When the primary filament or bulb burns out the system must automatically switch to the second bulb or filament. When the primary filament has failed, the system must provide an alarm to the LRT OCC that the secondary filament is being used so maintenance can be scheduled.

##### 7.18.1.3 Installation
All Signal heads should be mounted and aligned so that the Signal aspects are approximately at eye-level for the TO, or approximately 2.2 m to 3.0 m above Top of Rail (TOR).
7.18.1.4 Equipment Labelling
All new Block Signal and grade crossing Call-on Signal lights must be labelled with white letters and numbers on black background to match existing infrastructure.

7.18.2 Field Pushbuttons
The Signal System utilizes field pushbuttons throughout the system to allow for the manual operation of selecting a route.

7.18.2.1 Route Key Switch
Provision must be made to allow a TO to manually request a route from a Platform to the next Station.

The route request must be done via a keyed push button inside a locked enclosure on the Wayside. The key for the route selection enclosure must match existing keys used by the Operator.

7.18.2.2 Security Requirements
All field pushbuttons must be housed in a sealed enclosure that require a key for entry. A key is also required to activate the pushbutton after the enclosure has been opened to prevent unauthorized persons from activating the pushbutton should they gain access to the enclosure.

7.19 HARDWARE: TURNOUTS

7.19.1 General Requirements
All turnouts within the Signal System must be equipped with devices intended to hold the associated switch points mechanically secure for all Train movements and allow for persistent detection of the switch points being within tolerance distance from the stock rails for the intended movements.

Similar requirements must be employed for any other type of special trackwork that has segments of rail intended to move for routing purposes.

Refer to Chapter 5, Trackwork for track structure details.

7.19.2 Switch Point Detection
Switch point detection must employ Vital hardware and be able to declare:

- the switch points to be in the correct position for the points being up to 2 mm away from the stock rail
- the switch points to be not in the correct position for the points being more than 4 mm away from the stock rail

7.19.3 Switch Point Indicators
All turnouts on Mainline must be equipped with Switch Point Indicators (SPI). An SPI must display two separate indications, one for normal position and the other for the reverse position of the switch points.

The SPI aspect must not include Signal System switch correspondence, only the actual switch machine indication state. The SPI must be visible to Trains approaching in the facing point direction. The SPI is only intended to be viewed from the Train immediately in approach to the switch points.
7.19.4 Switch Machines
All switch machines installed on the LRT System ROW must be accepted for use in railway Signaling applications by recognized international regulatory body governing the installation of railway Signal Systems or have demonstrated successful operation for a period of more than five years at a location with similar winter climate conditions to Edmonton.

7.19.4.1 Control
Control circuits to operate a Wayside switch machine must feed directly from the SER or local bungalow controlling that switch machine. Status conditions from each switch machine include switch normal position and switch reverse position. The Signal System must derive the following status information: switch electrically locked, switch blocked, and switch disturbed alarm status.

All powered switch locations require keyed field control devices. Keyed controls must be located in a lockable enclosure adjacent to the switch machine. These controls allow the switch machine to be thrown by power while the switch is not electrically locked and local control of the territory is enabled.

All powered switches must support manual hand operation. While the switch machine is being controlled manually, it must disable motor control.

7.19.4.2 Construction
The switch machine must be electrically isolated and Bonded to ground.

The switch machine must be thermally insulated and heated to permit operation in a -40° C ambient temperature. The switch machine must also be rust-proof and weather-proof.

7.19.4.3 Acceptable Switch Machines
To maximize the efficiency of maintenance and training and to minimize spare parts requirements, the LRT Signal System has standardized switch machines. See the Approved Products List for the standard switch machine models. Any other model of switch machine requires written acceptance by the Engineer.

7.19.5 Hand-Thrown Switches
Manually controlled switches on Mainline are only permitted under temporary construction conditions or for turnouts not used with LRV operations. If the hand-operated device does not meet locking force requirements, switch locks and clamps must be employed to ensure adequate point holding force is attained.

A Switch Circuit Controller (SCC) must be employed to provide electrical contacts for interfacing to the Signal System to provide persistent Vital status of the switch position.

7.20 HARDWARE: TRACK CIRCUITS
Each track circuit along the LRT ROW must be monitored by a Vital track circuit device in the SER.

An audio frequency track circuit operates using specific audio frequencies. Adjacent track circuits use different frequencies so that track circuits can be distinguished from one another without the need for insulated joints. The occupancy is picked up in the SER by a solid-state Vital receiver. Audio frequency track circuits can be used in conjunction with insulated joints to improve the resolution of the track circuit limits. This is generally done at Block Signals.
7.20.1 Impedance Bonds
An Impedance Bond is a transformer that injects a track circuit signal onto the track so that it can be monitored to detect the presence of a Train. The impedance bond also allows the direct current Traction Power (TP) return path via the rails. Impedance bonds and supporting equipment must be rated according to the TP requirements.

All LRT extensions using track circuits for Train detection must be provided with the following:

- Impedance bonds and Insulated Joints to define the limits of track circuits
- Vital track circuit devices for the detection of Train occupancy

7.20.2 Connection to Rail

7.20.2.1 Cable Type and Size
Cables used to bond to the rails and connect TP paths must be insulated, multi-stranded aluminum conductors, flexible and capable of carrying the expected TP currents. Multiple cables may be used to achieve the current capacity.

Any track circuit connections not carrying traction currents must be of a plug bond style connector in accordance with AREMA standards.

7.20.2.2 Cross Bonding
Cross Bonding consists of multi-stranded, flexible cables in the TP circuit return path of the DC TP distribution system. They are connected between the centre-taps of an impedance Bonds of one track and connected to the impedance Bonds at the same location on another track.

The purpose of the Cross Bonding is to equalize the rail voltage drop between the two tracks. Cross Bonding is typically performed at negative return locations as well as locations approximately halfway between Traction Power Substation (TPSS). The size and number of cables must be chosen in conjunction with the TPS.

7.20.2.3 Track Circuit Design
The LRT Signal System utilizes Audio Frequency Track Circuits (AFTC) throughout the system. Insulated joints are installed only where definite resolution of Train detection boundaries is required, typically at Block Signals. Impedance bonds are installed at track circuit boundaries which allow for injection of the audio frequency energy into the track circuit while providing a proper return path for the DC TP.

7.20.2.4 Special Trackwork Bonding
All rails within turnouts and other special trackwork types must be bonded to the running rails. These Bonds must be capable of carrying the traction current requirements. Track circuit requirements may impose arrangements of Bonding and Insulated Joints to facilitate proper Train detection.

7.21 HARDWARE: TRIP STOPS

The LRT System uses the Siemens CTS/M Trip Stop system consisting of an onboard sensor component and a Wayside magnetic field device.
7.21.1 Magnetic Characteristics
The magnetic flux produced in the Train magnet by the track magnet is approximately 3 x 10^{-5} Wb (equal to 3000 M) at the absolute maximum distance of 160 mm.

7.22 HARDWARE: WHEEL DETECTORS
The Signal System uses Non-Vital wheel detectors for the following applications:

- To initiate automatic routing
- To initiate the timing sequence for a Speed Check

7.22.1 Installation
All rail-mounted components of a wheel detection system must be mounted below TOR and be must not be damaged by the passing of Trains or service equipment.

7.22.2 Directional Wheel Detectors
The existing Signal System uses directional wheel detectors. This is a two-part detection system that includes a rail-mounted detector and a Wayside electronic processor board. The detector includes an electronic proximity-sensing element that picks up the wheel flange of the passing Train. The Signal from this detector is transmitted, via cabling, to an oscillator on the processor board.

7.23 HARDWARE: CROSSING WARNING EQUIPMENT

7.23.1 Crossing Warning Signals
All crossing warning Signals must be designed in accordance with TCGCS. Equipment must be constructed in accordance with the AREMA C&S Recommended Practices Manual. Maximum allowable length for a gate arm in the city of Edmonton is 9.75 m.

7.23.2 Knife Switches
Knife switches must meet Vital circuit requirements found in AREMA Section 16: Vital Circuit and Software Design [9]. These controls must be enclosed, require a key for access/operation, and must allow the person using the control to have a clear view of the crossing signals it controls.

7.24 HARDWARE: WIRE CABLES

7.24.1 Standards
Wire and cable specifications and installation for Vital circuits must be in accordance with the AREMA Manual. Alternatively, external Vital circuit cables and the related test methods and procedures may comply with the CP-100 SCM-S-0930-01, Specification for 600 V polyethylene insulated and jacketed railway signal cable.

All other wiring must be in accordance with the CEC, Table 19.

For cables and wire installed in areas designated as tunnel sections and confined public areas:

- Cables and wire should comply and be installed in conformance with NFPA 130-8.6.7 [10]
- Cables and wire should be low smoke, halogen free type compliant with AREMA Communications and Signal Manual Part 10.2.13 [11]
• Cables and wire should be tested to Boeing Specification Support Standard BSS-7239 and comply with the following maximum gas release limits:
  - Carbon Monoxide (CO) - 3500 ppm
  - Carbon Dioxide (CO₂) - 90000 ppm
  - Hydrogen Fluoride (HF) - 200 ppm
  - Nitrogen Dioxide (NO₂) - 100 ppm
  - Hydrogen Chloride (HCl) - 500 ppm
  - Hydrogen Cyanide (HCN) - 150 ppm
  - Sulphur Dioxide (SO₂) - 100 ppm
  - Hydrogen Bromide (HBr) - 100 ppm

7.24.1.1 Wire Testing
NFPA 262 - Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces [12] should be used for testing wires.

7.24.2 Fibre Optic Systems
All fibre optic systems must be in accordance with Chapter 8, Communications.

7.24.3 Wire Identification
All circuit conductors must be labelled and tagged at both ends to identify the nomenclature of the circuit as well as the source and destination end location of the wire.

7.24.4 Duct Banks
The Signal duct bank is comprised of a suitable number of 100 mm RTRC ducts. The duct banks terminate at concrete vaults placed along the LRT ROW. Ducts for other communication services or for power cables may be located in the same trench. The Signal Design must be coordinated with the duct bank Design to ensure adequate cableway is provided.

All Signal cables must be uniquely identified within the duct bank system in a manner that will retain clarity.

Refer to Chapter 11, Electrical for detailed information on duct bank systems.

7.24.5 Equipment Identification
7.24.5.1 Numbering Schemes
All new equipment, relays, contacts and terminals for all LRT System extensions must be identified, located and numbered with a numbering scheme in accordance with the following sections.

7.24.5.2 Nomenclature
The following sections define the naming conventions used to identify equipment installed in the field. For any elements that are named based on meterage, they are based on the distance from an origin point at Churchill Station.

Designation
Most equipment on the line is identified by the chainage location of the equipment in reference to the chainage zero reference point south of Churchill Station.
Signals (Block and Call-on) and Wayside devices including cases and bungalows, are numbered based on distance from the chainage zero reference point south of Churchill Station.

**Bungalows and Junction Boxes**

Bungalows and junction box locations and drawings must be identified to reflect the chainage relative to Churchill Interlocking at that location.

### 7.24.5.3 Signals

The name assigned to a Signal is based on the following:

- Block Signals and Interlocking Signals must begin with a “B”
- The track on which the Signal is installed:
  - A Signal on the northbound track must include the designation “N”
  - A Signal on the southbound track must include the designation “S”
- A 3- or 4-digit numeric designation equal to approximately one tenth of the distance in metres between the Signal and the origin point at Churchill Station along the Trackway.

**Examples:**

- A Block Signal on the southbound track installed approximately 500 meters down the track from Churchill Station would be designated “BS050”
- A Call-on Signal on the northbound track installed approximately 3640 meters from Churchill Station would be designated “N364”

The numbering for Signals at the same location must use the same numeric value regardless of chainage differences per track.

### 7.24.5.4 Track Circuits

The name to be assigned to a track circuit is based on the following:

- The track on which the track circuit is installed
  - A track circuit on the northbound track must begin with the designation “N”
  - A track circuit on the southbound track must begin with the designation “S”
- A sequential numeric value
  - The track circuit is assigned a sequential numeric value unique within a Signal territory

For example, a track circuit on the northbound track could have the designation “N18T”. The two adjacent track circuits would be designated “N17T” and “N19T” if they were a part of the same Signaling territory.

The naming convention used for track circuits does allow for the same name to be given to different track circuits in the system. The naming convention used provides exclusivity only for an individual Signal territory.

**Turnouts**

A track circuit within a turnout is not given a track designation (ie. N or S) and the numeric value assigned to it is the same as the switch number. For example, a track circuit in the area for track switch 589 would be given the designation “589T”.
7.24.5.5 Speed Checks
The name to be assigned to a Speed Check is based on the following:

- A 2-letter prefix unique to the Signal territory name, such as ‘CO’ for Coliseum
- A 2-digit numeric designation. The numbers must start from the low chainage end of the territory and increment.
  - A Speed Check on the northbound track must have an odd number
  - A Speed Check on the southbound track must have an even number

For example, the third Speed Check on the southbound track installed in Churchill territory would be designated “CH05”.

7.24.5.6 Turnouts
Turnouts are simply assigned a numeric value. The turnouts nearest to the origin point at Churchill begin at 500 and switch numbers become progressively smaller for switches to the south and progressively larger for switches to the north. Starting at Churchill Junction the Metro Line switch numbers start at 700 and increase along the line to the north.

The four turnouts within a double crossover must be given four sequential numbers with odd numbers on the northbound track and even numbers on the southbound track. For example, the four turnouts for a double crossover north of Churchill Station could be 487 and 489 on the northbound track and 488 and 490 on the southbound track.

The numbers move sequentially along the system from south to north but where there is a considerable distance between switch points, a gap is left in the numbering system so that a new crossover between two existing crossovers will have numbers available to assign to the new track switches while maintaining the sequential pattern.

7.25 OTHER: SYSTEM INTERFACES
The Signal System must be designed to properly interface with other major system elements as follows.

7.25.1 Drainage
All devices that are located below grade or in proximity to the ground must be designed to ensure that adequate drainage is provided to prevent the accumulation of water, snow and ice.

7.25.2 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.

7.25.3 Traction Power Substation Return
The Signal Design must recognize that negative TP is connected to rails via the centre tap of the impedance bond.

7.25.4 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, location, and speed of Trains.

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 pre-emption function that optimizes pedestrian, cyclist, and motor vehicle movements through the Transportation Corridor.

Trains must pre-empt 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 to be 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 to be released.

7.26 OTHER: TESTING AND COMMISSIONING

All testing and commissioning must be carried out as described in Chapter 1, General.
REFERENCES


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8.0 COMMUNICATIONS

8.1 INTRODUCTION

This chapter outlines guidelines and criteria for the design of Communications infrastructure, subsystems and interfaces for LRT stations and platforms, Operations Control Centre, Server Rooms, Communications Rooms, Utility Complexes and related ancillary buildings throughout Edmonton’s High-Floor LRT system.

8.1.1 ETS Common Infrastructure Environment

The Operator is implementing a three-platform foundation design that will allow for greater visibility, maintainability, and standardization of its communications infrastructure and includes the following.

Network: The Operator is migrating to an MPLS based services architecture that will allow for multi-tenancy on the core network and deliver the strict network requirements demanded by Train control, Supervisory Control and Data Acquisition (SCADA), Closed Circuit Television (CCTV) and other services. This will form the backbone for the entire system and will be centrally monitored and controlled by the Operator.

Compute: The Operator is migrating to a common compute platform that will be standard across the board and be able to offer virtual machines or bare metal servers to any application that needs compute servers. This infrastructure will also be centrally monitored and controlled with provision for full failover and disaster recovery.

Storage: The entire compute platform will be migrating to a centrally managed Storage Area Network (SAN) solution that allows for boot from SAN and all storage necessary to run the applications. This will be centrally monitored and controlled and has the ability to back up all data.

These core platforms will be built with carrier grade equipment and the design and configuration will be deployed to provide 99.999% availability (five minutes downtime in one year) and can be fully maintained with minimum downtime of any service. The Operator is operating on a 24/7 basis and the systems must stay operational at all times. All communications subsystems will incorporate these core services into their design and deployment. Applications will be hosted on the Operator provided compute and storage platforms. Designers and suppliers will work closely with the Engineer, who will coordinate with the Operator to ensure that their needs are met.

All servers and devices are hardened to ensure the strictest levels of security and best practices for each particular 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.

The Engineer will arrange and coordinate with the Operator any additions or changes to the CIE core functionality or endpoint configurations. For more details on the current environment maintained by the Operator, refer to the Best Common Practice (BCP) document on the CIE.
8.1.2 Communication System Overview

The major subsystems and interfaces are shown in Figure 8.1 and include the following:

- 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 is a concept model; it is not to be confused with a complete set of drawings showing the physical or logical configuration of the CIE. It is intended to provide a view of the CIE architecture for discussion purposes only.
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 exemplify 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 normally housed in a Station equipment room.

Designs will utilize the Operator’s standardized and proven components whenever possible, to facilitate quality, availability and maintainability of facilities and communications subsystems. The standardized components are outlined in Owner/Operator Design Services Documents (DSDs) and BCPs.

8.1.4 **Naming Conventions**
For details on the current naming conventions maintained by the Operator, refer to the BCP document on naming conventions, which includes the following:

- Naming conventions for the various systems and system components
- Cable Labeling and Identification
- Cable Jacket and Wiring Color Codes

8.1.5 **System Integration**
All Design disciplines must coordinate their design activities with each other. System integration engineering will be needed to ensure that the many different Station and Right-of-Way (ROW) elements are properly interfaced. Refer to Chapter 1, General.

8.2 **CERTIFICATIONS**

8.2.1 **Railway Certifications**
- EN 50121-4 [1]
- IEC 62236-4 [2]

8.2.2 **Regulatory Compliance**
- European Telecommunications Standards Institute (ETSI) Standards
- American National Standards Institute (ANSI) Standards

8.2.3 **Electrical Safety Compliance**
- UL 609550-1 [3]

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 [4]
- IEC/EN 61000-4-3 Radiated Immunity [5]

8.2.7 Safety Standards Compliance

- FDA CDRH 21-CFR
- UL/CSA 60950-22 [6]
- CSA-C22.2 No.94.1 [7], CSA-C22.2 No.94.2 [8]
- CAN/CSA-B72-M87 [9]
- UL50 [10]
- IEC 60529 [12]
- 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 stricter 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:

- Alberta Chemical Hazards Regulations
- Alberta General Safety Regulations
- City of Edmonton Community Standards Bylaw 14600 (noise provisions) [14]
- Canadian Electrical Code C22.1-18 [15]
- 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 62.1 [17] and ASHRAE 62.2 [18]
- ANSI/IES-RP-7-17 – Recommended Practice for Lighting Industrial Facilities [19]
• CSA-Z412 – Guidelines on Office Ergonomics [20]
• 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
• Insulated Cable Engineers Association (ICEA) (latest edition)
  • ICEA S-87-640 - Optical Fiber Outside Plant Communications Cable [21]
• Telecommunications Industries Associations (ANSI/TIA) (latest editions)
  • ANSI/TIA-568-D [22]
  • ANSI/TIA-568.2-D: Balanced Twisted-Pair Telecommunications Cabling and Components [23]
  • ANSI/TIA-942-B [24]
  • ANSI/TIA-606-C [25]
  • ANSI/TIA-607-D [26]
  • TIA-102.x Series: Telecommunications, Land Mobile Communications (APCO/Project 25) [27]
• Building Industry Consulting Service International (BICSI) (latest editions)
  • ANSI/BICSI 007: Practices for Intelligent Buildings and Premises [28]
  • ANSI/BICSI 002: Data Center Design [29]
  • ANSI/BICSI 005: Electronic Safety and Security (ESS) [30]
  • ANSI/BICSI 006: Distributed Antenna Systems (DAS) [31]
  • ANSI/BICSI 008: Wireless Local Area Network (WLAN) [32]
  • ANSI/BICSI N2-17: PoE Installation [33]
  • BICSI G1-17: Outside Plant (OSP) - General [34]
  • ANSI/NECA/BICSI 607: Bonding and Grounding [35]
• Institute of Electrical and Electronics Engineers (IEEE) (latest editions)
  • IEEE 802.1 series [36]
  • IEEE 802.3 series [37]
  • IEEE 802.11a/b/g/n [38]
  • IEEE 802.16d WiMAX [39]
  • IEEE - C62.41.1 [40]
• International Telecommunication Union (ITU) (latest editions)
  • ITU-T G.652: Characteristics of a single-mode optical fibre and cable [41]
  • ITU-T G.984: GPON Gigabit-capable Passive Optical Networks [42]
  • ITU-T G.988: ONU management and control interface (OMCI) [43]
• Telecordia (latest editions)
  • Telecordia GR-1089-CORE [44]
  • Telecordia GR-63-CORE [45]
• Internet Engineering Task Force (IETF) (latest editions)
  • RFC 791 - IPv4 [46]
  • RFC 2460 - IPv6 [47]
  • RFC 2475 - QoS/DiffServ [48]
8.3.2 Approved Products List
Designers must refer to an Approved Products List provided by the Engineer and Operator.

8.4 GENERAL DESIGN REQUIREMENTS

8.4.1 Design Goals and Objectives
Designs will minimize the number of components utilized in communication systems and all systems must be designed with integration in mind. Physical segregation of common system equipment in communication rooms must be avoided. All operator functions must be capable of being installed and utilized 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. All new systems must include a Design and Specification Document (DSD) to describe how the system functions within the Operator’s system. Consistency from one site to another must be applied. The organization and layout of most types of communications facilities is well established and must be followed in deployment of new sites.

The Total Cost of Ownership (TCO) must be considered for a communications system solution. Various factors will be considered including capital costs, maintenance costs, costs of adds, changes and deletes, 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 and meeting requirements specified by the Engineer. Any interconnections and dependencies between systems such as timing; functionality; hardware, wiring, network interfaces, or software interfaces; will 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 is an important consideration for every point in the system: power, cooling, network connections and local hardware.

8.4.2 Equipment, Devices, and Components
All equipment must be remotely manageable both in band and out of band.

All servers are centrally located in the two main data centres. Communications designs that require servers will be based upon server platforms that will be located in these data centres as part of the CIE.

Designs will be coordinated and accepted by the Engineer with input from the Operator.

Any new devices that are not currently used by the Operator and are being proposed as part of a project must be reviewed by the Engineer, who will consult 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 19-inch rack mounted and capable of being densely installed. Chassis-based modular units with redundant power supplies must be used. Individual units that each have their own power supply, such as media converters that do not share a power supply for multiple runs, are not permitted.

8.4.3 Powering
All communications equipment must be powered by a high availability power source. 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.

Power and data will be carried on the same cable where possible and allow for centralized management of all end devices down to the power level. Ideally, all end devices would have the capability to be remotely power cycled. A high availability centralized power source at the Utility Complex will be provided. A Power Over Ethernet (PoE) adapter will convert centralized DC power per end device. Powered fibre solutions must be used for any device beyond 90 m of a network switch.

The goal for end device DC power must be to have it powered from a central DC power source at the closest Station. Individual stand-alone power units, such as a UPS contained in a remote cabinet must be avoided. Any exceptions must be reviewed by the Engineer.

Power may be a range of DC voltages from 12 Vdc to 57 Vdc. Refer to Chapters 6, Traction Power and Chapter 11, Electrical for more details.

### 8.4.4 Cabling, Splicing, and Connectors
All indoor backbone fibre splicing will 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 will be documented in the Design.

All proposed cables and connector types for a project will be documented in the Design.

### 8.4.5 Wireless Solutions
Wired connectivity should be provided wherever possible. When it becomes necessary to consider wireless connectivity, for example a remote camera on a parking lot pole, all design details must be documented in the Design and approved by the Operator.

### 8.4.6 Remote Power Control/Management for Power Over Ethernet (PoE) Devices
Designs and installations will provide the ability to remotely power cycle any PoE device such as a phone or camera. For PoE powered devices, network switches, PoE injectors and PoE midspans will be manageable and can remotely power cycle the end device.

### 8.4.7 Entrance Conduits and Terminal Blocks
Conduit should enter the room at either ceiling level or floor level, located on a single wall, preferably the side of the room nearest to the Trackway or system-wide duct-bank. The Design must include a 20 mm fire treated plywood (telco grade) backboard, painted grey. 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 will also hold gas tube protector cabinets, wall mount fibre splices, and the associated cable management. For more information refer to the Operator’s BCP document on entrance conduits and terminal blocks.

### 8.4.8 Low Voltage Conduits and Distribution
Wall mounted cabinets for systems such as BMS, card access control and RTUs 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. For more information refer to the Operator’s BCP
document on low voltage conduits.

**8.4.9 Surge Arrestors**

All outdoor CAT6 runs must have surge arrestors installed at the base of the device to prevent surges
from entering the communications room.

All outside plant copper cables must be terminated on gas-tube protector (lightning protector) blocks such
as Porta Systems 175BCXN-400 or Circa Building Entrance Terminals 1880ECM1-25 (UL497)

All cameras installed outdoors must have a 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, as per the manufacturer’s specifications and meeting
CAN/CSA-B72-M87 [9], UL-497B [49] and TIA/EIA 607 [26] 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 will 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.

**8.4.10 Grounding**

Grounding design will mitigate the effects of ground loops and electromagnetic interference. The
Designer must provide chassis ground and signal ground systems as follows. The chassis ground will tie
into the building traditional ground system along with other systems in the building. The signal ground is
referenced to the circuit devices and is isolated from the chassis ground. The primary reason for this is
that Signaling and Traction Power Systems (TPS) can feed noise back through the ground system.

The Design must use oversized main ground bus bars, ERICO TMGB-A25L33PT or approved
equivalent. Resistance to earth from each ground bus bar will be 10 Ω or less for chassis ground and 5 Ω
or less for signal ground.

A ground wire must have its own two-hole lug connector to attach that wire to the ground bus bar.
Bolting a ground wire with a two-hole lug to a bus bar with two bolts prevents the lug from rotating
which will eliminate stress on the ground wire and prevent the possibility of the connection rotating
loose. Double-lug connections where multiple ground wires are attached to one lug are not permitted.

**8.4.11 Equipment Racks**

Equipment racks must comply with E.I.A. specifications for rack mounting ANSI/EIA standard RS-310
[50].

For more information on specifications and type approved equipment racks, refer to the Operator’s BCP
document on equipment racks.

**8.4.12 Cable Tray Structure**

Design of cable layout within cable tray structures and conduits must minimize coupling of induced
voltages and crosstalk between cables belonging to various systems. 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 will have the following characteristics:

- The distance between PA system audio cables and any telephone, CAT6, or power cable is maximized
- Fibre cables are physically isolated from copper cabling
- Cables entering or exiting the cable tray are protected with cable waterfalls
- The signal ground bar is 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 Vac and 24/48 Vdc distribution is placed 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

### 8.4.13 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.

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 will include the following:

- Network devices
- PoE injectors
- Telephone gateways
- Amplifiers
- PDUs
- UPS
- Video encoders
- Remote PA servers
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- Radio Bi-Directional Amplifiers (BDA)

8.5 COMMUNICATION CABLELING REQUIREMENTS

Cabling design must ensure that suitable products are used and that there is consistency in designs and installations on the communications system.

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 will 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 will meet the following minimum 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

8.5.1 Cabling and Wiring Methodologies

All cabling designs and installations must follow communications standards listed in Section 8.4, including the latest BICSI and TIA standards.

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 meters long and continuous from jack-to-jack
- Installing plugs on either end and plugging directly into devices is unacceptable
- If a device requires CAT6 wires to be screwed down to terminals, then a CAT6 pigtail (for example, see Belden C632206xxx: patch cord with one end cut off; RJ45 to blunt) will be used. Cutting off the jack in the field is not acceptable
• All copper and fibre cables must be kept separate within communications cabinets and cable management raceways
• Copper is kept to the left side and fibre is kept to the right side
• All power connections will be organized in the rear of the cabinet

Maximum fill ratio of any conduit will not exceed 40%. All conduit 90° bends require communication elbows that have a bending radius of 11-times the cable diameter. Electrical 90° fittings or bends are not acceptable in communications wiring. There will not be more than 180° (2x90°) of cable and conduit bends allowed between pull boxes.

Cabling to devices at outdoor locations will require a surge suppressor at the base of the device and at the building cable entrance points, which must be connected to ground.

For more information on cabling and wiring methodologies, refer to the Operator’s BCP document on cabling and wiring.

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. For more information refer to the Operator’s BCP document on configuration management software.

8.5.2 Cable Toxicity Requirements
Project specifications will cover toxicity requirements for cables on a case-by-case basis where the cable toxicity specifics will be based upon the application.

For example, cables installed in tunnels, or enclosed spaces where people may be present will have specific toxicity limits covered by project specifications.

Common cable type designations for low toxicity cables are as follows:

• Low-Smoke, Zero-Halogens (LSZH)
• CMP FT6 plenum rated cables have a low smoke FEP (fluorinated ethylene propylene)

The Boeing smoke toxicity test BSS7239 is a test that checks for the following limits:

• Carbon Monoxide (CO) < 3500 ppm
• Carbon Dioxide (CO2) < 90000 ppm
• Hydrogen Fluoride (HF) < 200 ppm
• Nitrogen Dioxide (NO2) < 100 ppm
• Hydrogen Chloride (HCl) < 500 ppm
• Hydrogen Cyanide (HCN) < 150 ppm
• Sulfur Dioxide (SO2) < 100 ppm
• Hydrogen Bromide (HBr) < 100 ppm

8.5.3 Data and Telephone Cooper Cables
8.5.3.1 Minimum Requirements
Copper cables must conform to the following minimum requirements:

• Conductors must be 22 AWG, or larger, tinned copper, meeting Canadian Electrical Code 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) that will meet 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 [21] 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 with 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 only on the north or west end of the cable (single end grounding) to prevent ground loops

8.5.3.2 CAT6 Cooper Cables
All horizontal data and voice cables will meet or exceed CAT6 standards as per ANSI/TIA-568-D [22].

8.5.3.3 Multi-Pair CAT3 Cooper Cables
Multi-pair copper voice/analog cables will meet or exceed CAT3 standards as per ANSI/TIA-568-D [22].

- Conductors: 25-pair 24 AWG solid copper conductors
- Cable groups: formed into binder groups of 4 pairs
- Insulation: thermoplastic-covered individuals; riser-rated overall jacket, complying with requirements of CEC
- Colour coding: each conductor colour coded in accordance with industry standard colour scheme for 25-pair, 50-pair, 100-pair, and 200-pair cables. Each conductor tracer-coloured
- DC resistance: maximum 94 Ω/km
- Mutual capacitance: maximum 262 pF/100 m @ 1 MHz
- Characteristic impedance: 100 Ω ± 15%
- Attenuation, maximum:
  - 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 will be greater than or equal to 171 dB @ 1 km @ 1510 kHz and 82 dB @ 1 km @ 10 MHz

8.5.3.4 Multi-Pair CAT3 Outside Plants Cooper Cables
All Outside Plant (OSP) copper cabling will meet the requirements listed above for multi-pair CAT3 copper cables

All OSP copper cabling will 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 will be sunlight resistant.
8.5.4 Fibre Optic Cables

8.5.4.1 Outside Plant Fibre Optic Cables
All OSP fibre optic cables will be suitable for installation and operation in underground ducts, cable trays, open air and subway systems or other areas where uncontrolled temperature and humidity exist and/or where cable may be exposed to water and pest damage. Cable must be of loose tube, gel filled design having buffer tubes, central dielectric member (non-metallic), and 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 [22] and GR-20-CORE [51].

Fibre cables must meet the requirements of TIA 568-D [22] and GR-20-CORE [51].

Buffer tubes – the optical cable must be loose tube, gel-filled design with up to 12 colour coded fibres contained within loose tubes filled with water blocking gel. The loose buffer tube filling must be made of 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 [52].

Cabling – buffer tubes must be cabled around the central member using either a helical stranding or reverse oscillation method. Fillers may be used to maintain the cable geometry. The interstices between the tubes must be filled with a water blocking gel similar in property to that 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 desired 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 will meet the following minimum requirements:

- Sunlight resistant
- Suitable for direct burial
- Does not promote 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 [21] – 15 kN/m (IEC 60794-1-2 E3) [53]

Cables must meet all other requirements of direct burial outside plant cables as listed by GR-20-CORE [51] and ICEA S-87-640 [21] 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 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). Markings must be of a contrasting colour, either black or white, and must be indented into outer jacket

### Table 8.1 Single Mode Fibre – Performance Requirements

<table>
<thead>
<tr>
<th>Performance Requirement</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Diameter</td>
<td>8.2 – 8.8 microns</td>
</tr>
<tr>
<td>Diameter</td>
<td>125 Microns +/- 7 microns</td>
</tr>
<tr>
<td>Type</td>
<td>Step index</td>
</tr>
<tr>
<td>Cladding</td>
<td>≤ 2.0%</td>
</tr>
<tr>
<td>Minimum Bend Radius</td>
<td>≥ 10x cable diameter</td>
</tr>
<tr>
<td>(No load)</td>
<td>≥ 20x cable diameter</td>
</tr>
<tr>
<td>Attenuation:</td>
<td>≤ 0.35 dB/km @ 1285 - 1330 nm</td>
</tr>
<tr>
<td></td>
<td>≤ 0.22 dB/km @ 1525 - 1575 nm</td>
</tr>
<tr>
<td>Cut-off Wavelength</td>
<td>≤ 1260 nm</td>
</tr>
<tr>
<td>Zero Dispersion Wavelength</td>
<td>1310 ≤ Wavelength ≤ 1324 nm</td>
</tr>
<tr>
<td>Zero Dispersion Slope</td>
<td>≤ 0.092 ps/(nm²*km)</td>
</tr>
<tr>
<td>Environmental Induced Attenuation</td>
<td>≤ 0.05 dB/km @ 1310, 1550 nm</td>
</tr>
<tr>
<td>For Water Immersion</td>
<td>23°C +/- 2°C</td>
</tr>
<tr>
<td>For Humidity Cycling</td>
<td>- 10°C to +85°C up to 98% RH</td>
</tr>
<tr>
<td>For Temp Dependence</td>
<td>- 50°C to +85°C</td>
</tr>
<tr>
<td>Proof Test Stress</td>
<td>≥ 100 kpsi (0.7 GPa)</td>
</tr>
<tr>
<td>Coating Diameter</td>
<td>245 + 5 microns</td>
</tr>
</tbody>
</table>

### 8.6 CABLES IN STATIONS & FACILITIES

The cabling requirements for Stations and Ancillary Facilities must meet the following minimum requirements. No hydroscopic gel may be used. If cables will be placed in a wet location, additional protection must be obtained with 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 8.6.3. 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.
8.7 CLOSED CIRCUIT TELEVISION

The CCTV system allows operations personnel to remotely monitor and record activities at all Stations and other designated locations.

8.7.1 Architecture
The CCTV system utilizes 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 will be GSC architecture and no alternate video systems or platforms are allowed.

The GSC system is constructed 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 located in the ETS CIE. In addition, there are several sites with on-site archivers due to limited WAN bandwidth availability at the time of their deployment. These will be migrated to the centralized storage servers once the WAN bandwidth is increased.

Cameras, encoders, input/output modules (alarm units), and client workstations located throughout the Operator’s facilities are all 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 VMS, the Operator utilizes a centralized device management platform for all CCTV field devices, such as cameras, encoders & 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. Refer to the Operator DSD on CCTV and GSC System.

8.7.2 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 utilized to allow for closer inspection of areas of concern, which may reduce the overall number of fixed cameras in a given coverage area.

8.7.2.1 Security Surveillance
Camera coverage is required for security sensitive areas. Refer to Chapter 15, Safety and Security.

8.7.2.2 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 determine Passenger load 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 employees access doors or entrances must have CCTV coverage
- CCTV coverage for both access locations and inner areas must be provided for substations, communications rooms, and signals rooms
- All At-Grade crossings in the LRT System, both pedestrian/cyclist and motor vehicle, must be covered with a fixed view camera to allow monitoring of crossing arm position and to assist with post-incident investigations. Multiple cameras or a multi-head device may be required to provide sufficient viewing detail

8.7.3 Lighting/Illumination
Typical installations must not require additions or modifications to the lighting in place, unless otherwise provided for under a renovation or remodeling project. If a camera is in a room or location where there is zero-light condition, consideration may be given to providing dedicated lighting such as infrared or white-light LED illuminators. These illuminators must be specifically 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.

8.7.4 Closed Circuit Television Cameras
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.

8.7.4.1 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 [3]
- Product safety standards as defined in IEC/EN/UL 60950-22 [6]
- Relevant parts of SMPTE 296M (HDTV 720p) [54]
- Relevant parts of SMPTE 274M (HDTV 1080p) [55]
- ISO/IEC 14496-10 MPEG-4 part 10, advanced video coding (H.264) [56]
- ONVIF profile S [57] or ONVIF version 1.01 [58] or higher as defined by the ONVIF organization
- EMC approvals:
  - EN 55022 Class B [59]
  - EN 55024 [60]
  - FCC Part 15 - Subpart B Class A + B [61]
  - VCCI Class B [62]
  - RCM AS/NZS
  - CISPR 22 Class B
  - ICES-003 Class B [63]
  - KCC KN32 Class B
  - KN35
  - KCC KN22 Class B
  - KN24
- Mechanical and environmental standards:
  - IEC/EN 60529 [12]
  - IP66/67 [64]
  - ISO 20653 [65]
  - IP6K9K [66]
8.7.4.2 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)

8.7.4.3 Camera Lenses
All cameras must include 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, will be selected to suit the installation and field-of-view requirements. No after-market lenses or optics may be used on new cameras.
8.7.4.4 Pan/Tilt/Zoom Functions
PTZ cameras must contain 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° 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 “auto 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.

8.7.4.5 Image Control
The following features must be provided:

- The unit must have automatic and manual white balance
- The camera must have wide dynamic range - providing up to 120 dB dynamic range
- The camera must have an electronic shutter operating in the range of a minimum 1/100,000s to 2s
- The camera must incorporate Highlight Compensation (HLC) and Backlight Compensation (BLC)
- The camera must provide a function for optimization of low light behavior
8.7.4.6 Video
The following 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 with automatic scene adaptive bitrate control
- The camera must for its H.264 implementation support scene adaptive bitrate control with automatic dynamic ROI to reduce bitrate in un-prioritized regions into lower bandwidth and storage requirements

8.7.4.7 Storage
The following 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.
- These will be ruggedized industrial storage cards with a minimum of 21 days of video storage – refer to the Operator’s BCP on video storage
- The camera must support recording to network attached storage

8.7.4.8 Connectors
The camera must be equipped with an RJ45 100BASE-TX/1000BASE-T PoE ethernet port.

8.7.4.9 Power
The following power features must be provided:

- Uninterruptable, high availability power must be supplied to CCTV devices
- Cameras will be powered by PoE supplied by the network switch, a PoE midspan, or, in a GPON architecture, through two-conductor DC power in a hybrid fibre cable

8.7.4.10 Camera Mounts
The following features must be provided:

- Camera mounts must be designed specifically for use with the specific cameras
- Placement of these mounts must allow the camera to provide the view desired by the Operator, while considering maintenance requirements
- Mounting brackets must be compatible with the poles or structures that will be used at a location including ceiling mounts, wall mounts, corner mounts, pole mounts, and parapet mounts

8.7.4.11 Camera Poles
For pole-mounted cameras, dedicated camera mounting poles will meet the following requirements:

- Camera poles must have a square section measuring 4.75 inches x 4.75 inches
• Total camera pole height including the pole base must be 18 feet
• The pole mounting base must be 13 inches x 13 inches
• Constructed from extruded aluminum with powder coat finish
• The pole must mount directly onto a NEMA 4 rated base box measuring 15 inches x 18 inches x 22.5 inches (See Moog P1800 specification for further detail)
• Where applicable, the pole should include the internal camera lowering mechanism
• Pole should include internal CAT6 cabling from manufacturer to accommodate connection of camera to base of pole while allowing necessary cable retraction during lowering process (See Moog PV18N specification for further detail)
• Where a single pole will be used for mounting two devices, the manufacturer’s dual-mount adapter must be used. For fixed poles this would be a separate accessory (see Moog PV8). Where a lowering mechanism will be used, the pole must be replaced with the dual-mount model (see Moog PV18NX2 specification for further detail) which includes a dual mounting adapter and two internal Cat 6 cables
• In all cases, poles should be equipped with manufacturer’s lightning rod (see Moog PV1) and anchoring jig (see Moog PV4)
• Refer to the Operator’s BCP on camera poles and accessories

8.7.4.12 Security
Security will meet the following requirements:

• 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

8.7.4.13 Application Programmers Interface and Applications
The following Application Programmers Interface (API) and Applications are required:

• 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 open and published API providing necessary information for integration of functionality into third party application
• Cameras must comply with relevant ONVIF profile as defined by the ONVIF Organization

8.7.4.14 Network functionality
The following network functionality is required:

• 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

8.7.4.15 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

The camera must support audio encoding as follows:

- AAC LC at 8/16 kHz
- G.711 PCM at 8 kHz
- G.726 ADPCM at 8 kHz

8.7.4.16 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

8.7.4.17 Other Functionality
The other following functionalities 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 a 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

8.7.4.18 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 are 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 offer significantly higher sensitivity levels in low light than Type 2 cameras. In addition, Type 1 cameras 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. Refer to the Operator’s BCP for specifications and type approved Type 1 cameras, which are currently Axis Q36XX-VE Series (Q3617-VE model).

8.7.4.19 Fixed Camera Type 2
Type 2 cameras may be used in locations where lighting is more evenly controlled and lighting conditions are more consistent. Cameras may still be exposed to extremely bright light or glare and must adjust dynamically to these conditions. Type 2 cameras will not 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. Refer to the Operator’s BCP for specifications and type approved Type 2 cameras, which are currently Axis Q35XX-VE Series (Q3505-VE model).

8.7.4.20 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, the PTZ camera may be an interior rated device. Refer to the Operator’s BCP for specifications and type approved PTZ interior cameras, which are currently Axis Q6055 Series.

8.7.4.21 PAN/TILT/ZOOM (PTZ) Cameras – Exterior Application
Exterior unitized PTZ cameras to allow for expanded coverage of larger areas and to provide tracking options during critical events. Where cameras must operate in temperatures below 0° C or high moisture levels, the 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 down to -40° C and be environmentally rated. The camera must operate in a humidity range of 10 to 100% RH (condensing).

Refer to the Operator’s BCP for specifications and type approved exterior PTZ cameras which are currently Axis Q6055-E.

8.7.4.22 Alarm Interface Device
Alarm interface devices provide an interface between external dry contact “alarm points” and the Genetec security system. All alarm-point connections will be to an alarm interface device.

There are several different alarms that are passed to the Genetec security system. They include:

• Help phone activation
• Panic alarm activation
• TVM door opening
• Service door openings

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.

Refer to Operator’s BCP for alarm interface devices.

### 8.8 PUBLIC ADDRESS/VARIABLE MESSAGE SIGN

The PA/VMS consists of a PA system that provides automated announcements of Train arrivals and allows ETS staff to make public announcements in all Stations and Transit Centres, and a 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 Train control system and the communications network.

Refer to the Operator DSD for operations, network and software details of the PA/VMS.

#### 8.8.1 Public Address System

All Stations and Platforms are equipped with amplified public address voice messaging systems. Stations have loudspeakers on the Platform and 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.

#### 8.8.1.1 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. As a minimum criterion, the system must comply with the noise provisions of the City of Edmonton Community Standards Bylaw 14600 [14].

#### 8.8.1.2 Acoustic Conditions and Treatment

Products must be selected to ensure that the PA system delivers high speech intelligibility, even when operating in a reverberant and raised ambient noise environment.

Station materials and finishes should be limited to those that reduce acoustic reflection and complement the goal of maximizing PA system performance. As a design goal, the RT60 should be kept to less than one second, where RT60 is defined as the time it takes sound pressure to be reduced by 60 dB after the sound stops. Should RT60 be more than one second, computerized models, such as Enhanced Acoustic Simulator for Engineers (EASE) by AFMG, should be used to determine optimal speaker locations and acoustic treatments to achieve intelligible messaging.

#### 8.8.1.3 System Acoustic Performance

Loudspeakers should be placed to provide consistent and uniform sound levels throughout designated speaker zones. The following acoustic performance levels should 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 [14]
• 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

**8.8.1.4 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 assure 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 from Platform and fitted with vandal resistant housing and hardware. Speakers are will be tapped at 5 W.

PA automatic volume control systems should be considered in Stations. Ideally the volume control system should be able to automatically compensate for high wind or a high background noise environment.

Designs should consider using IP speakers.

**8.8.1.5 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
• Power rating that is suitable for individual loudspeaker zones
• Integrated 70 V constant line operation
• Ability to monitor the health of all connected speaker zones
• Integrated Digital Signal Processing (DSP) and ambient noise sensing functions
• Integrated ability to play out messages
• Network connected, remotely manageable and configurable
• Connected to a central backend system that monitors all amplifiers on the system

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 will be a 70-volt constant current method.

Refer to the Operator’s BCP for PA amplifiers and audio controllers.

8.8.1.6 Signal Processing
To assure 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.

Refer to the Operator’s BCP for network access Controllers.

8.8.1.7 Conduit and Wiring
All PA wire, cable, and connectors must be run in electrical conduit, junction boxes and backboxes.

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 cable must not run in the same conduit as high level loudspeaker cable.

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.

8.8.1.8 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.

8.8.1.9 Integration of Public Address System to the Telephone System
The PA system must interface to the telephone system, so that Train Operators can make announcements at Stations and various other locations using the telephone system. The PA/VMS has a SIP registration to the Cisco Unified Communication Management (CUCM) system.

8.8.2 Variable Message Sign
8.8.2.1 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.
Refer to the Operator’s BCP for Variable Message Signs.

8.8.2.2 Installation Guidelines

- No overhead single sided signs on Platform areas (unless mounted to a wall)
- Outdoor signs should be under a rain shield
- All signs should be visible to a camera on both sides (note that PTZ cameras cannot look upwards from their mounting height)
- VMS signs should not be in line with Wayfinding signs as they block sight lines for each other
- Light from scrolling VMS signs can give false positives to BMS motion sensors. This effect is more pronounced at night when the Station's lights are off as the VMS light is visible for a longer distance
- VMS signs should be below catenary height and at least 2 m from high voltage lines to allow maintenance personnel to access them without a TP shutdown, unless a physical barrier is in place.
- Enough signs must be mounted to ensure that Patrons can see a VMS sign in all areas of the Platform.
- The signs should be visible to Patrons entering a Platform
- Signs should be mounted high enough that Patrons can not touch them
- All enclosures should be NEMA 4 using water-tight connectors for wiring and be able to withstand power washing without water ingress at any location
- Conduits or connections which run to the signs but originate from a high moisture area (under a Platform or other unheated or unconditioned space) should be sealed after installation
- VMS signs should be on BMS controlled power circuits for remote power cycling

8.8.2.3 Connectivity
VMS must be IP-based and connected to the Operator’s CIE.

8.8.2.4 Electrical Power
All VMS must be powered by conditioned UPS back up power and also fed from the Station primary AC power supply. All VMS equipment power must be on the same phase.

8.9 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 Operator’s use:

- ROW phones
- Staff service phones
- Platform call on phones
- Equipment room phones
- OCC phones

Other phone connections copper and wireless:
• Fire Alarm System (FAS) auto-dialers

Telephone systems provide emergency and non-emergency voice communications for all LRT facilities.

The telephone system utilizes a CUCM System. Cisco VoIP phones are located in the LRT OCC. Each Station is equipped with Cisco phones. The CUCM system will manage all the phones for different services. Each phone connects 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. Call details are logged for all these phone calls to determine call volumes. The phone system is able to produce reports that show the number of calls received in the LRT OCC over a given time period. Voice recordings can be retrieved from the call logging server for review and analysis.

8.9.1 Automated Device Testing

All emergency phones, information phones and security phones must be automatically tested. This is a remote test of a phone’s network connection, call button and/or off-hook switch. This is critical to ensure that the phone is working at all times. When a failure is detected, maintenance personnel will be notified to resolve the issue in a timely manner.

8.9.2 Integrated to Public Address/Variable Message Sign

8.9.2.1 Right-of-Way Phones

ROW phones should be installed at nominal 350 m spacing intervals along the LRT Corridor and connected to cables and vaults that are part of the LRT communication duct bank. ROW phones will use VoIP technology and a 2-pair fibre optic cable to connect each ROW phone.

ROW phones must also be installed at each crossing Controller and at tunnel portals, in tunnels and at each Cross-connection. A blue light must be installed at these phone locations.

ROW phones must be heavy duty, weather-proof, and have an armored handset cord. Examples include Guardian Telecom ACT-40 for analog phones with ATA or ACT-40-V for VoIP phones.

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 from ROW phones to a number outside the LRT network is blocked.

8.9.2.2 Call on Phones

Stainless steel call on phones must be installed at each end of all Platforms. For staff security, a mirror must be installed on the inside of the door to the phone compartment. This phone must be a Guardian SCT-10 or SCT-10-V.

8.9.2.3 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 Traction Power Substation (TPSS), it may be more practical to locate the demarcation point outside the substation to minimize the footprint of the telecom isolator.

Alarm, trouble, and supervisory conditions will be sent to a ULC approved Fire Signal Receiving Centre (FRSC). This is a code requirement to meet CAN/ULC-S527 [82] and CAN/ULC-S559 [83] for primary signal transmission compliance. The fire alarm signal will also be simultaneously sent to the LRT OCC. Refer to Chapter 12, Mechanical for additional details.

8.9.2.4 Emergency Phones
Emergency phones must be located as follows:

- On Platforms next to entry/exit points, next to information panels, in elevators, and near seating areas
- On Station Concourse levels in fare paid areas close 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 alarm is programmed to move the closest PTZ cameras to focus on the help phone causing the alarm and bring up the camera in the main control room so ETS security has visual awareness of the emergency situation.

Emergency phones are programmed as an auto ring down telephone line to the LRT OCC.

Refer to Operator’s BCP for Emergency Phones.

8.9.2.5 Elevator Help Phones
Elevator help phones should be provided by the elevator company and will be interfaced with the LRT OCC using an auto ring-down connection.

8.9.2.6 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 OCC. Public washroom locks are controlled through a phone system interface.

8.9.2.7 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.

8.9.2.8 Information Phones
Information phones must be located next to or built into information panels located at Platform and Concourse levels.

Information phone calls are an auto ring-down line to “311” and are answered by a City of Edmonton 311 operator.

8.9.3 Signage
Signage for phones including information phones, emergency phones, elevator help phones, and washroom access phones must also be provided in braille for visually impaired or blind Patrons.
Refer to the Operator’s BCP for Telephones.

8.9.4 Call Recording
All emergency, elevator help, and washroom access calls are recorded.

The current standard for voice logging is NICE. All radios and VoIP telephones are recorded by NICE.

8.9.5 Caller ID Conventions
Caller ID will use the Operator’s conventions. Refer to the Operator’s Caller ID BCP.

8.10 RADIO SYSTEMS

This section presents the guidelines that must be followed in the design of the radio system for future extensions to the LRT System. It also provides an overview of the radio system currently in use on the LRT System.

The LRT System 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.

Refer to the Operator’s Radio Systems BCP.

8.10.1 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 considerations. Currently, lithium chemistry batteries are used for maximum battery life and light weight. NiMH, NiCad, and lead acid batteries are not permitted.

8.10.2 Mobile Radios
Mobile radios must meet TIA-102 (APCO P25) standards and must be 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.

8.10.3 Tunnel Radio System
The tunnel radio system uses the normal Operator’s mobile radio for communication. The radios utilize a radiax cable which runs along the inside of the tunnels. The radio signals are carried back to the nearest communication rooms where they are repeated through the BDA system to ensure reliable radio connectivity throughout all the LRT tunnels.

8.10.4 Distributed Antenna System
The DAS will utilize a hybrid fibre and coax infrastructure solution engineered in a redundant configuration. The DAS receives RF signal from the base station or off-air BDA 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. Usually, a central headend BDA drives the passive DAS elements or radiax cables.

Active DAS provides improved installation and maintenance benefits over passive DAS, but still poses some design challenges including limited range and increased system noise. Active DAS is the preferred in-building wireless solution over passive DAS for large facilities.

The Operator’s DAS must meet the following basic 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 system must include software configurable frequency configuration, system gain and RAU output power
- DAS system must support industry standard cabling options
- DAS system must support modular and scalable system equipment
- DAS system must be deployable in environments with potentially high levels of RF interference while maintaining acceptable levels of operational reliability
- DAS system must not require separate power connections to the unit’s antennas
- DAS system 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 within the LRT System and must provide signal coverage of 95% or better in public and non-public areas inside Stations and inside tunnels

8.10.5 Bi-Directional Amplifiers
The Operator’s BDA system currently consists of approximately 14 BDA locations throughout the LRT System facilities. These systems have been installed in locations that have been identified as having poor coverage for radio units, especially portable radios. The primary need for this system is in tunnels and any other low-lying areas surrounded by concrete.

Each BDA site has its own donor antenna at the surface pointed at the downtown tower site and the signals are redistributed internally via radiax cable. None of these sites are managed remotely and the only indication of system problems is when the Operator’s personnel report issues.

Going forward, this system will be replaced to accommodate the P25 system and new frequency band that will be used by AFRRCS. As part of the upgrade, new radiax will be installed in the tunnels and designed to effectively cover the tunnel space. As well, the system will be fibre fed from two donor locations to ensure reliability and the cleanest signal possible. Every BDA will also be connected to the Operator’s network for remote diagnostics and monitoring of every device. This will allow for proactive alerting of potential issues that can be rectified promptly.

8.10.6 Radiax Design
The design of the LRT radio system utilizes radiax ‘slotted cable’ antenna systems. Radiax cable is installed within 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 mounted on insulated standoff hangers. All radio channels employ segments of the existing radiax antenna systems for tunnel radio coverage utilizing BDA and low pass filters.
8.10.7 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 to allow for 99% reliability in all Train radio communications. This is usually expressed in terms of min dBm level expectations in the Transportation Corridor which ensures 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

Coverage testing will sample points along the Transportation Corridor and other critical coverage areas and consider areas where changes have occurred to structures from the initial construction drawings. A 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 period of time (for example: minimum 1x10⁻⁸ BER over a 1 hr test period) to ensure testing credibility, accuracy, and reliability.

8.10.8 At-Grade Stations (Including Terrestrial Coverage)

Radio coverage must adequately serve ground level radio communications for Trains and At-Grade Stations as coverage currently extends beyond the south city limits. Any Station with rooms or accessible areas below ground level will require treatment with BDA or active DAS technology similar to tunnels and underground Stations. Currently Coliseum and Grandin Stations have BDAs.

8.10.8.1 Wire and Cable Requirements

All wire and cable required for radio systems must meet CEC requirements for terrestrial and below grade construction.

All wire and cable must be installed in conduit and appropriate electrical boxes and EEMAC approved equipment cabinets.

8.10.8.2 Cable Hanger Requirements

Insulated ‘stand off’ cable hangers for radiax antenna cable must be as specified by the manufacturer (Andrews Antenna Products or approved equivalent) of radiax cable and fixtures.

8.10.9 Radio System Operations and Control Software

The control features and operating software of any future system must be compatible with existing radio systems technology and equipment and be forward compatible with new wireless network technologies.

8.11 SIGNALS WORK

8.11.1 Conventions

The Signals network must be interfaced to the CIE. The two types of switches used to interface to the main Operator network are Signals Room Routers (SRR) and Territory Ring Routers (TRR).

Refer to the Operator’s Signals network BCP for details of the standardized Signals network.
8.11.2 Redundancy
All Signal switches are connected in a dual layer 2 managed ring that provides redundant failover paths.

8.11.3 Monitoring of Devices
All Signals devices are currently monitored with a central Operator’s SNMP monitoring platform for a single view into the health of the Operator’s systems and the Signals network. Going forward, monitoring of the Signals network will be accomplished with a single view into the Operator’s entire network which the Signals network will be a portion of.

8.11.4 Signals Fibre Backbone
To reduce the chance of issues with 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 spliced directly from the backbone into the Signals room and the only location any changes can 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.

8.12 TRACTION POWER NETWORKS

8.12.1 Architecture
The TP network consists of three separate networks. One is a ring that starts at Churchill and picks up the five southernmost substations on the Capital line. In addition, Churchill and the entire Metro line are connected to this network. This network has a gateway and a fibre connection to EPCOR in Churchill Station. All the rest of the substations in the system are connected on the second network which is via ISDN lines from the substations to EPCOR. The final network type is a linear line of switches to interconnect the transfer trip signaling from adjacent substations.

8.12.2 Transfer Trip
The transfer trip function allows for a substation that detects a major overload condition to be able to send a signal to the adjacent substation to also trip its breakers to avoid creating more overloads down the line. 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.

8.12.3 SCADA Control
The status of protective relays, transformers, 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. Refer to Chapter 6, Traction Power.

8.12.4 Redundancy
The SCADA network has ring redundancy, but the transfer trip network does not. This functionality must be incorporated into future designs using MPLS as well as for one converged architecture and network.

8.12.5 Traction Power Fibre Backbone
To reduce the chance of issues with 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 spliced directly from the backbone into the TP room and the only location any changes can be made is in the TP room with EPCOR supervision.
8.12.6 Monitoring of Devices
None of these devices are currently monitored due to the history of how the network was built. This will be updated with a new converged network. Refer to Chapter 6, Traction Power.

8.12.7 Optical Isolation
The RTUs in the TPSS are connected with fibre for optical isolation from high power electrical equipment. CAT6 copper connections to switches are not allowed and all connections from RTUs to switches must be fibre optic to prevent any surges from damaging the network devices.

8.13 OTHER SUBSYSTEMS
Several other subsystems require communications support such as the Smart Fare payment and collection system and the intrusion detection and card access control system.

8.13.1 Smart Fare System
Smart Fare Vending Machines (SFVM) and Smart Fare Validators (SFV) will require power and network connectivity at Stations and Platforms. Refer to Chapter 10, Station and Ancillary Facilities.

Refer to the Operator’s BCP on the Smart Fare system.

8.13.2 Intrusion Detection and Card Access Control System
The Owner has implemented the Tyco C-Cure security system. In some cases, the Operator may provide network connectivity through a fire-walled connection. The following devices must be provided:

- Magnetic door contacts
- Door strikes
- Bolt monitors
- Door holders

The LRT OCC must be able to monitor and control access to exterior doors during unoccupied periods with occupancy scheduled alarming. Access to all interior doors to non-public spaces must be monitored and 24/7 alarming at doors not regularly accessed or high security areas must be provided. Occupancy scheduled alarming at doors 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 and details can be found 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. These interlocks are via dry contacts from the C-Cure system.

8.13.3 Public Wi-Fi
The Owner is committed to providing Patrons and the public with a free public Wi-Fi service at all Stations and Transit Centre locations. The objective of the public Wi-Fi network is to provide reliable “best effort” wireless communications for Patrons and the Operator’s personnel in underground and surface or elevated Platforms and Transit Centres.

Wi-Fi communications technologies and Station infrastructure must be coordinated with Open City Wi-Fi to support their connectivity requirements.
Wi-Fi service is provided by the City of Edmonton Corporate IT department. Refer to the City of Edmonton website for more information.

**8.13.4 Third Party Advertising**
The Owner contracts with third party advertisers who provide electronic signage at all Platforms and in Transit Centres.

To support this advertising platform, the Designer must consider conduit pathways, cabling infrastructure, power, and network capacity in Station communications systems design. The details of power and network connectivity must be part of commercial discussions between the third party advertisers and the Owner.

**8.13.5 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 as existing 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.

**8.13.5.1 ATMs**
Public ATMs will require pathway conduits for both power and network connectivity back 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.

**8.13.5.2 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.

**8.13.5.3 Coffee Shops and Portable Food Kiosks**
Coffee shops and portable food kiosks will likely require communications, power, potable water, and/or sanitary sewer service 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.

**8.14 TESTING AND COMMISSIONING**

Refer to Chapter 1, General for details on Testing and Commissioning.
REFERENCES


[64] NEMA, "NEMA Enclosure Types," [Online]. Available:


[66] Panasonic, "What is IP6K9K?," Panasonic, [Online]. Available:


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9.0 STRUCTURES

9.1 INTRODUCTION

This chapter presents structural design guidelines, requirements and standards for design of 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

Listed codes, standards and reference guidelines must conform to the most current edition.

9.1.1.1 Codes and Standards

- CSA S6 - Canadian Highway Design Code (CHBDC) [1]
- CSA S413 – Parking Structures [2]
- Alberta Building Code (ABC) [3]
- National Building Code of Canada and Commentaries (NBC) [4]
- Alberta Transportation - Bridge Structures Design Criteria (AT-BSDC) [7]
- Alberta Transportation - Standard Specifications for Bridge Construction [8]
- AASHTO LRFD Bridge Design Specifications (AASHTO LFRD BDS) [9]
- American Railway Engineering & Maintenance of Way Association (AREMA) [10]

9.1.1.2 Technical References

- Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130) [12]
- Track Design Handbook for Light Rail Transit [13]
- Recommendations for Stay-Cable Design, Testing, and Installation [14]
- Technical Manual for Design and Construction of Road Tunnels - Civil Elements [16]
- Guidelines for the Design of Footbridges [17]
- Road traffic noise reducing devices [19]
- Metro Rail Design Criteria, Section 5 Structural [21]
- AISC Design Guide 11: Vibrations of Steel-Framed Structural Systems Due to Human Activity (AISC 11) [22]

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 — ETS Standard Operating Procedure [23]
9.1.2 Service Life and Design Life
See 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 detailed Design submission must include a draft inspection and maintenance section that identifies critical areas of the structure, the frequency of inspection, and guidelines and 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

<table>
<thead>
<tr>
<th>Structure Category</th>
<th>Structure Type</th>
<th>Primary Design Standard</th>
<th>Secondary Design Standard</th>
<th>Design Life (years)</th>
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<tbody>
<tr>
<td>Transportation Structures</td>
<td>Bridges</td>
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<tr>
<td></td>
<td>Track Slab</td>
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<td></td>
<td>Portals and Approaches</td>
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<td></td>
<td>Noise Attenuation Walls</td>
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<td>Stations</td>
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<td>Traction Power Substations (TPSS) and Utility Complexes</td>
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<td>Electrical Ductbanks and Vaults</td>
<td>ABC</td>
<td></td>
<td>75</td>
</tr>
</tbody>
</table>

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 required dimensions for the Trackway and designated egress Walkways and associated Refuge Zones are discussed in Chapter 15, Safety and Security. Emergency egress design must follow the requirements of NFPA 130 [12].

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 ballasted 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 outlined 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 breakaway prior to failure 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 the pole breakaway anchorage. Refer to AASHTO LFRDLTS [15] 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, has 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 the 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 emergency gress 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 can be located within the minimum Vehicle Running Clearance Envelope (VRCE). The design of emergency egress from tunnels must follow NFPA 130 [12].

9.5.1 Mined Tunnels
Mined tunnels are 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, and 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.

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 [16] and Metro Rail Design Criteria [21] for the design of LRT tunnel linings.

9.5.1.1 Alignment and Tolerances
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 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 upon 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 be a minimum of 600 mm unless otherwise approved by the Engineer.
Joints that allow movement (construction, expansion, contraction) should 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 the restraint forces.

Cast-in-place concrete slabs and walls must incorporate measures to accommodate movement resulting from temperature change and shrinkage. Control joints must be provided at a spacing of no more than 15 m to limit shrinkage stresses and cracking. 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 45° from vertical must be designed as a tunnel.

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 may be the case for a tangent pile wall, the system must provide free, year-round, 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 discussed 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-gGrade 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. The 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 [20]. 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

All Station types are described 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 [3] for use and occupancy.

#### 9.7.2 At-Grade and Elevated

Platform height and edge clearance dimensions are referenced in Chapter 3, Clearances and Right-of-Way.

To avoid resonant vibrations induced by 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 structures 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 designed according to ABC [3]. 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.

### 9.8 TRACTION POWER SUBSTATION AND UTILITY COMPLEXES

TPSS design must be in accordance with ABC [3] to support mechanical and electrical systems and use and occupancy described 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 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 [1], 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. The DLA for global effects is based on EN 1991-2 with standard track maintenance assumed.

\[ DLA = \Phi - 1, \quad 0 \leq DLA \leq 1, \]

Where, \( \Phi \) is the dynamic factor according to EN 1991-2 [11].

Note: that 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 is to 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 is 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 Ballasted Track
For ballasted 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 can 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 can assume that the wheel loads are uniformly distributed over a length of 900 mm along the rail. This load can 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 [10]. Consideration should be given to combinations of acceleration and braking forces where the structure includes more than one track.

For ballasted track with Continuous Welded Rails (CWR) spanning the entire bridge structure, the Designer can 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 [10].

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 [1] with “v” being at least the maximum design speed of the Train.

Nosing/Hunting Forces
A 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.

9.9.6 Derailment Forces
Train derailment load, including both vertical and horizontal loads, must be treated as a collision load, "H", in CHBDC [1].

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 is to 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. Guardrails or barriers protecting the track must be designed to resist this force. Refer to Track Design Handbook [13].

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 [1].

9.9.8 Rail-Structure Interaction Demands

Loads created by rail-structure interaction must be considered and used as thermal loads, "K", in CHBDC [1].

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 ballasted 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, ballasted track produces minimal thermal interaction forces between rail and structure.

Direct fixation involves attaching the rail to 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.

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. See 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 [13] 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/m³. Snow load must be treated as a live load “L” in CHBDC [1] 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 [3].

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 for design of the retaining structure is 20 kPa. 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/m³.

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 onto private property located 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 [1], LRT structures must be designed for:

$$\alpha_D \times D + \alpha_E \times E + \alpha_P \times P + 1.0 \times L + 1.25 \times K + 1.5 \times (W+V)$$  \hspace{1cm} \text{ULS Combination 4a}

Where, $\alpha_D$, $\alpha_E$, and $\alpha_P$ = 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 [14].

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.

$$\alpha_D \times D + \alpha_D \times E + \alpha_D \times P + 1.5 \times L + \text{CEF}$$  \hspace{1cm} \text{ULS Combination 10}

$$\alpha_D \times D + \alpha_D \times E + \alpha_D \times P + 0.75 \times L + 1.1 \times \text{CLDF}$$  \hspace{1cm} \text{ULS Combination 11}

LRT Structures erected using segmental construction must account for load combinations in accordance with AASHTO [14].

9.10.2 Serviceability Limit State

9.10.2.1 Deflection Criteria
Short and medium span bridges must meet deflection limitations of CHBDC [1] 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 here are based on international practice for long span railway bridges as reflected in Eurocodes EN 1990 [24] and EN 1991-2 [11], German Institute of Standardization (DIN) Fachbericht 101 [25], and UIC (International Union of Railways) Technical and Research Reports: D160/RP6 [26]. 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 \( \theta_1 + \theta_2 < 5 \text{ mrad} \), where \( \theta \) 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 [25].

**Criterion 3: Maximum Angular Rotation – Horizontal Plane**
The maximum relative rotation in horizontal plane at joints between adjacent spans must be limited to \( \theta_1 + \theta_2 < 3.5 \text{ mrad} \), where \( \theta \) is the horizontal rotation in load combination SLS 1. Refer to Eurocode EN 1990/A1 Section A2.4.4.2.4 – Table A2.8 [24] for railway speeds \( V \leq 120 \text{ km/h} \).

**Criterion 4: Maximum Transverse Slope of LRT Track**
The maximum transverse slope of LRT tracks must be limited to \( \theta_T < \pm 20 \text{ mrad} \) for SLS 1 containing LRVs, and \( \theta_T < \pm 30 \text{ mrad} \) for SLS 1 containing the work Train, where \( \theta_T \) 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) [27] and TCRP Report 57 [28] 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 \( \kappa < 1 \text{ mrad/m} \) for SLS 1 at the location of any LRV, and \( \kappa < 1.5 \text{ mrad/m} \) for SLS 1 at a work Train location, where \( \kappa \) 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) [24]) for railway bridges with design speeds \( \leq 120 \text{ km/h} \). 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 [27], [28] 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 [29].
Criterion 7: Runability – Overturning Risk
Wheel unloading coefficient $\Delta P/P$ must be limited to $\Delta P/P < 0.9$ for SLS 1 using the operating Train speed. Factors $\Delta P$ 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 [30].

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 [1] 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 is to 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 [17] and Technical Guide Footbridge.

Vertical acceleration in publicly accessible areas of Stations and Platforms must not exceed limits specified in AISC 11 [22]. 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 [1] for calculation of fatigue damage can be used with following amendments:

$$\lambda_1 \cdot f_{sr} < F_{sr}$$

Where, $\lambda_1$ = 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 $\lambda_1$ 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 $\lambda_1$ 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 [5].
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) [5] supplemented by sections of the Alberta Transportation Standard Specifications for Bridge Construction [8]. In the event of conflict, the more stringent provision applies.

9.11.1 Special Requirements for Mined Tunnels
In addition to construction tolerances outlined 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
FIGURE 9.2
RECOMMENDED AREA OF TUNNEL SECTION AT PORTAL
REFERENCES


[23] Edmonton Transit System, LRT Infrastructure in LRT Tunnels: Publication Number 0.02, Edmonton: City of Edmonton, 2006.


CHAPTER 10
Stations and Ancillary Facilities
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10.0 STATIONS AND ANCILLARY FACILITIES

10.1 GENERAL

This chapter provides the guidelines and criteria for the design of all Stations, associated Patron amenity areas and other related facilities for the 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 are required to maintain consistency with ETS branding and identity. This will ensure that the design of Stations and Ancillary Facilities remains consistent 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 is required between all design disciplines to ensure the Station and Right-of-Way (ROW) systems, assemblies, components and materials are properly incorporated and integrated. 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 Alberta Building Code (ABC), some of their operational characteristics do not align with normal building functions. Stations and Ancillary Facilities must be designed to meet all 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 Operator and the Engineer.

Refer to Chapter 1, General for variance or design exception procedures.

10.1.1.1 Codes and Regulations Pursuant to the Altera Safety Codes Act

- National Fire Code (NFC) [2]
- National Energy Code for Buildings (NECB) [3]
- Elevating Devices Codes Regulation [4]
10.1.1.2 Policies and Bylaws
- City of Edmonton Zoning Bylaw 12800 [5]
- City of Edmonton Bylaw 14054: Edmonton Design Committee Bylaw [6]
- City Policy C602 Accessibility for People with Disabilities (supersedes C463, C466 and the ETS Accessible Transit Instruction)
- City Policy C532 Sustainable Building [7]
- City Policy C588 Winter City Design Policy [8]
- City Policy C458C Percent for Art to Provide and Encourage Art in Public Areas [9]
- City Policy C573A Complete Streets [10]
- City Policy C565 Transit Oriented Development [11]
- City Policy C554A Park and Ride [12]

10.1.1.3 Reference Standards
- NFPA 14 - Standard for the Installation of Standpipe, Private Hydrants, and Hose Systems [14]
- Safety Code for Elevators and Escalators [16]
- APTA Heavy Duty Transit Escalator Design Guidelines [17]
- Guideline on Durability in Buildings [18]
- Parking Structures [19]
- Lighting for Exterior Environments [21]
- Test Method for Measuring Wet DCOF of Common Hard-Surface Floor Materials [22]
- CSA B651-18 Accessible Design for The Built Environment [23]

10.1.1.4 Guidelines
- Complete Streets Design and Construction Standards (CSDCS) [26]
- Transit Oriented Development Guidelines [27]
- Winter Design Guidelines [28]
- Park and Ride Guidelines [29]
- City of Edmonton High Floor, Urban Style LRT Sustainable Urban Integration Guidelines
- Clearing Our Path: Creating Accessible Environments for People with Vision loss [32]
- ETS Graphic Standards Manual: LRT Signage, Light Rail Transit
- ETS Brand Guide
- Commissioning Consultant Manual, Volume 2 Building Envelope Commissioning and Process Guidelines [34]
- Crime Prevention Through Environmental Design (CPTED) Principles [35]
- Parking Structures [36]
- Road and Walkway Lighting Manual [37]
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 [27] 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 categorizes 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 are required 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 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 10.2.1 and Section 10.6.6 for 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 TO 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 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 must be included in all local and Multi-Modal Stations. 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 [29])
- 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 the TO, as directed by the Engineer
### 10.7 Table 10.1 Station Classification

<table>
<thead>
<tr>
<th>Station type</th>
<th>Transportation mode</th>
<th>Station components and amenities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>Category includes all active modes, public transit users, and other Patrons accessing Stations via: SUP, Cycle track, Bus stop, Drop off laybys (Kiss &amp; Ride/taxi/ride share), Paratransit priority loading areas</td>
<td>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</td>
</tr>
<tr>
<td>Multi-Modal</td>
<td>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</td>
<td>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)</td>
</tr>
</tbody>
</table>

### 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 should 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 should 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 should
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 should 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, should be durable, easy to maintain and should minimize life cycle maintenance costs.

Station lighting can have a substantial impact on the quality of the Patron experience and their real and perceived safety. The lighting colour spectrum should be as close to natural light as possible to bring out the true colour of objects. Lighting should be constant, uniform, and diffused, and glare should 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 dark sky compliant.

Light fixtures and standards should be incorporated into the architectural elements of the Stations as much as possible. City Policy C532 [7] should be applied, where applicable and practical.

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 specified 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 when designing all 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 should 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) should 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 are required 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 are required.

Platforms and shelters should be provided with a variety of seating, some of which should include seating with backs and arm rests. Refer to Section 10.7.1.

Station Designs should consider using the same general layout features 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 that can 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 sightlines
- Provide the ability for others to see them, so that the feeling of isolation is reduced
- Provide adequate and appropriate lighting
- Avoidance or minimization of confined or hidden areas

Security features such as emergency telephones and Closed Circuit Television (CCTV) surveillance cameras are to be an integral feature of the Station design and Station-related public areas.

The Designer must provide a report that identifies how CPTED 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 outlined in greater detail in Chapter 15, Safety and Security.

**10.4 EMERGENCY EGRESS/EXITING**

**10.4.1 Alberta Building Code (ABC)**

Emergency egress from Stations or Ancillary Facilities must conform to the latest edition of the ABC and must be reviewed and approved by the AHJ. For all LRT facilities in Edmonton, this jurisdiction resides with the Engineer. 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 ABC 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:
10.10 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) 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 ABC as discussed above, it is recommended that the Designer review the NFPA 130 [13] documents due to their general acceptance by the North American transit industry with respect to fire safety issues. More specifically, NFPA 130 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 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, bedsteads 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 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 ABC. In addition, commercial or retail areas must independently meet all relevant code requirements.

Special attention should 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 observed:

- 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 takes place, temporary exits must be provided pending availability of permanent exits in the new facility
• Exit rights and agreements cannot expire on change of land or building ownership
• Appropriate cost sharing agreements must be established
• All agreements affecting the ABC requirements must be irrevocable
• Security must be maintained for both the Station premises and the privately-owned property
• The ABC must not be violated by any changes to structure location, mechanical, and electrical systems

10.4.3.3 Emergency Egress Lighting Requirements
Illumination levels for emergency and egress conditions for interior and exterior locations are specified 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 in the above section, Station entrances must be designed to avoid queuing and consider bi-directional flow of Patrons to and from Platform areas. If doors are required, door widths should be designed to avoid congestion. All ramps, stairs, and passageways (including escalators and elevators, if required), should provide safe, Accessible, convenient, and direct access to and from the Station.

Notwithstanding the requirements of NFPA 130, 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 the 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 should be avoided.

Cross flow of Patrons is highly undesirable and should be avoided, particularly at fare vending and validation area and decision points. The Designer should provide adequate space so that queues at fare collection areas do not block Patron flows. Dead-ends and unnecessary turns should always be avoided.

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 be avoided, especially in areas where there are elevation changes.

Elevators and stairs must be provided to Grade Separated Stations, even if escalators are present. Access to other 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 ABC. 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 to assess the requirements for queuing and surge areas based on projected ridership, requirements for timed exiting as per NFPA130, the ABC, 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 are required to 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.

Emergency egress must satisfy the requirements of NFPA 130. 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 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 ABC and NFPA 130. The minimum acceptable width of passageways for non-public use is 900 mm. For public use pedways the passageway width (exit width) must be determined by the requirement to meet a point of safety within six minutes, as per NFPA 130, but not less than 4000 mm. The minimum clear height should 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 is required to 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 ABC and the City of Edmonton Access Design Guide and the Barrier Free Design Guide [25]. The clear distance between handrails must consider the need for motorized snow removal equipment on the ramps and must be a minimum of 900 mm wide. The Designer must confirm minimum requirements with the Operator.

10.5.3.2 Stairs
At minimum all stairs should meet the requirements of the ABC, the City of Edmonton Access Design Guide and Barrier Free Guide. Open risers are not permitted and nosing of stairs should 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 are to 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 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 should 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 [25] 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 should meet the requirements of the ABC, the Barrier Free Design Guide and the City of Edmonton Access Design Guide. Handrails should be terminated by returning the ends into the 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 are required at Platform ends, set back a minimum of 300 mm from the edge of the Platform. Vertical railing supports are to be welded flush to preinstalled embedded anchor plates.

10.5.3.4 Escalators
At minimum, all escalators should meet the requirements of the Alberta Safety Codes Act (ASCA), including the ABC and the Alberta Elevating Devices and Amusement Ride Safety Association (AEDARSA). Escalators should also meet the requirements of Safety Code for Elevators and Escalators [16] and should comply with the American Public Transportation Association (APTA) Heavy Duty Transit Escalator Design Guidelines [17].

Escalators should be included in Station designs based on consideration of the following conditions and design criteria:

- Exiting requirements as governed by ABC and NFPA 130
- 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 30° from the 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 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 ABC and AEDARSA, the City of Edmonton Access Design Guide, and the Safety Code for Elevators and Escalators [16].

In general, the incorporation of elevators into the design of Stations is to 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 practical and necessary to provide an elevator for Barrier-Free access to Platforms, a minimum of two elevators should be included at each Station to increase flexibility for provision of access during maintenance. The
The requirement for additional elevators is dependent on entranceway, interior circulation and Barrier-Free Accessibility requirements. Elevator access locations are to be as weather protected as practicable.

The Designer must adhere to the following requirements in designing elevators:

- A minimum capacity of 1134 kg must be provided
- Minimum inside dimensions must be 2032 mm x 1295 mm
- Access control must be provided from the Security Operations Control Centre (OCC)
- The use of graffiti-resistant finish materials in the cab interior is required
- At least one transparent side in the elevator car at each stop position must be provided
- Flooring must meet the Operator’s requirements for maintenance, durability and slip resistance
- Lighting must be covered with a protective transparent shield to limit vandalism
- Machine rooms, if required, must be in close proximity to the elevator and must be acoustically treated to minimize noise
- Oil heaters must be installed in hydraulic elevator storage tanks if the elevator is not in a heated area
- A self-recharging battery pack must be provided 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 is required
- All elevator keying must match the keying of the existing elevators within the LRT System
- Elevators must be equipped with “Home” interface for fire alarm system input signal as per the requirements of Chapter 11, Electrical
- All electrical & mechanical systems must conform 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 should not be located at a mounting height lower than the lowest 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 levels for the interior and exterior of elevators and at control panel locations

10.6 STATION DESIGN

Stations may be in either centre-running or side-running LRT alignments 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 Side-Loaded Staggered Stations (At-Grade)

Side-loaded staggered Stations consist of two side-loaded Platforms staggered 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.
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 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 typically include a Concourse level.

Underground Stations will 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 ABC and NFPA 130.

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, projected ridership, and constraints on available LRT ROW.
10.6.2.2 Platform Length
Platform length is a minimum of 123 m, but where practicable 130 m length should be provided. 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.

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)
- 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 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 given 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.

The absolute minimum distance from the TOR to the underside of the catenary contact wire is 4200 mm. This applies where vertical clearance is restricted such as within enclosed Stations and tunnels. Refer to Chapter 3, Clearances & Right-of-Way for requirements and figures. For Stations where there is no canopy over the Trackway, the minimum distance from TOR to the underside of the catenary contact wire support is 4800 mm. Adequate separation/safety barriers to the catenary system from surrounding structures must be provided.

The Station Designer must coordinate with the OCS Designer to ensure 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 shelter, 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 should slope at a minimum of 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 flooring 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) 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 the Service Vehicles are required 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. A hatch or doorway at track level should be provided but may not always be feasible. 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 ABC.

The crawl space must include drains to intercept water and must have a concrete surface on any exposed soil to reduce the potential for mold formation. Refer to Chapter 16, Utilities and Drainage and Chapter 9, Structures.

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.
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 are required. Canopy roofing must include:

- Provision of skylights to allow natural daylight to reach the Platform
- Provision of roof access for cleaning and maintenance
- Fall protection measures that form a permanent part of the roof structure
- Provision of snow stops where required
- Bird deterrent surfaces and/or minimal opportunities for bird roosting

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.

10.6.3.1 Fall Protection
The Designer must provide an engineered fall protection system and fall restraint systems for roof structures that require cleaning and inspection for maintenance purposes.

10.6.3.2 Drainage
Roof assemblies must be designed to prevent ponding of water on the roof to prevent excessive live loads and damage to the roofing assembly. Sloped roof structures are preferred. Roof drain locations must be coordinated with the design of 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, are required. 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 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 are required. Exterior Platform Canopies must incorporate dimmable fixtures tied to daylight sensors. Architectural or accent lighting to enhance building features must meet the requirements for 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 provided in Chapter 11, Electrical.

10.6.4 Platform Shelters
Sheltered enclosures, designed to protect Patrons from wind, rain and snow, are required on all outdoor Platform areas. Doors are not required for shelters to promote ease of circulation and minimize maintenance. Shelters must accommodate the required wheelchair turning radius as outlined in the Access Design Guide.

Shelters may be designed to incorporate a vestibule or wind break for fare payment and ticket validation equipment. Alternatively, a separate, standalone vestibule area can be provided for this equipment. Where glass shelter walls are used, graphic visual film as per the Access Design Guide must be included in the Design.

The number of shelters to be provided 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 entrances to control heat loss.

10.6.4.2 Radiant Heat
Overhead electric infrared and gas heaters are acceptable as heating devices in shelters. 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. Refer to Chapter 8, Communications and Chapter 12, Mechanical.

The Designer should also consider placing heaters in other areas of the Platform, particularly near fare equipment.

10.6.5 Design Coordination
The Station Design must achieve minimal visual clutter and distraction in and around Stations. Where possible, the design of Stations should limit areas of exposed conduit, rainwater leaders, piping, gas lines, grounding wires, unnecessary signage, or surface mounted hardware through design 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 will 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 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 should be provided.

Directional signage leading to public washrooms must be provided in accordance with the LRT Graphics Standards Manual. Washroom signs should be included on exterior entrance signs.

Washrooms must be heated. Refer to Chapter 12, Mechanical.
All washroom fixtures and accessories should meet the requirements of the ABC, the Alberta Barrier Free Guideline [24] and the City of Edmonton Access Design Guide [25]. Additionally, the design of washrooms must meet the following Owner requirements:

- Floors and walls must be tiled
- Glossy or highly polished finishes are not acceptable
- Washbasins should be built into a counter or vanity
- Hot water service is required
- 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
- Paper towel dispensers and sanitary napkin disposal units are required in each stall or washroom
- 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, lit “Occupied” sign located near the washroom doorway and activated by motion sensor inside the washroom must be provided
- 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 beside the door, inside the washroom is required
- A doorway sensor must be provided to prevent closing on an occupant

10.6.6.2 Staff Washrooms
Staff and TO washrooms are required when security, inspectors, or maintenance staff are housed at a Station and where a Station is designated as Terminus Station. For TO washrooms, a minimum of two unisex washrooms should 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 require two individual stalls and two urinals
• Female washrooms require two individual stalls
• TO 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 are to 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
• Water service
• Built-in shelving or cabinets
• Washbasin built into a counter or vanity
• Mop sink with appropriately sized backsplash
• Space for floor scrubber

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.
• 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
• 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.
• Nearby heated parking (or exterior parking with plug-ins) for two staff
• Card reader access

10.6.6.7 Vacuum Room
Vacuum rooms are required 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 is preferred to facilitate access for the track mounted equipment that will handle the dust collection barrels. The vacuum system equipment components should be placed in a separate room that it is at track level or is accessible by elevator to the track level. 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 the 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.

Galvanized steel vacuum outlets must be provided at 20 m spacing under the Platform overhang for both tracks.

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 must be provided.
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 the cash vault at a Station if required. The Operator will provide the Designer with detailed design and related installation requirements.

Electrical service outlets must be provided as follows:

- 15 A 120 V split receptacles at 20 m intervals under both sides of the Platform overhang
- 15 A 120 V split receptacles at all landings of stairs and escalators
- Twist lock receptacles must be used at locations that are accessible by the public

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 feasible, provide a hose bib at both ends of the Platform.

Refer to Chapter 11, Electrical and Chapter 12, Mechanical for additional information.

10.7 FURNISHINGS, ART, AND EQUIPMENT

10.7.1 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.

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.

10.7.1.1 Benches & Leaning Rails
Platform benches must be provided and must be durable and maintenance free (metal construction is preferred). Seating must provide options for armrests and backrests to enhance Barrier-Free Accessibility.

Benches should be designed to limit 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, will be developed by the Designer in consultation with the Operator.

10.7.1.2 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 Passenger 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
The City of Edmonton Art in Public Places Policy [9] requires incorporating artwork in public areas of LRT facilities. 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 will coordinate their activities to ensure 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 OCC. Based on the type of Station, electrical systems may be distributed through a main electrical room or marshalling cabinets.

Refer to Chapter 8, Communications for system requirements, function and design, and integration with other systems and facilities, such as TPSS and Signal System infrastructure.

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 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 OCC staff to make announcements to Patrons in all Stations. PA system details are provided in Chapter 8, Communications.

10.7.3.4 Variable Message Sign (VMS) System
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.

**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 should 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 is 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 be consistent with 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 throughout the Platform. A minimum of eight validators are required 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 validators with the Engineer and Operator.

Each Platform must have a minimum of two SFVM, centrally located and spaced approximately 20 to 40 m apart. Placement of SFVM must consider equipment service access, clearances, and pedestrian circulation, including Barrier-Free requirements. All operable controls should 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 to 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 wheelchairs 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 validators will be determined based on Station characteristics and Platform type. SFVM must be sheltered from wind and rain. Fare equipment should 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 Corporate Accessibility Policy and the Access Design Guideline.
10.7.3.10 Non-Fare Revenue Stream Equipment
Non-essential Platform equipment required as a revenue stream opportunity for the City 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 vandal resistance as other Platform equipment.

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 ETS, 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 system and customer information or wayfinding signage including emergency exits or equipment. Panels must be located to 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 in the Station design process to allow coordination with electrical design.

Vending Machines and Electronic Equipment
The Design must consider the required service connections for vending machines. Coordination and placement of all equipment should 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 possible. Newspaper boxes should be anchored to a post to secure the box.

Free Newspaper Or Magazine Boxes
Free newspaper boxes should be located at main Station entranceways, although interior passageways may also be acceptable.

Automated Teller Machines (ATM)
ATM should be located in the general vicinity of fare collection equipment. Electrical and data line service is required.

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.
10.7.4 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.

10.7.4.1 Signage
Both static and electronic signage is required 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 is 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 is provided on Platform and may incorporate interactive digital information or advertising. Digital Train arrival VMS is located on Platform to provide “next Train” information and may include other news or advertising.

Static regulatory signage provides direction to emergency phones, SFVMs, and validators, 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 outlined in Chapter 14, Urban Integration.

10.7.4.2 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. Preference is to be given to locations adjacent building entrance points, and large-scale walls or flat surfaces facing public approaches. Suitable locations are to be determined jointly by the Designer and the Operator. Logo details will be provided by the Operator.

For lettering on buildings, the Design must use anodized, chrome plated, or powder coated metal lettering 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.

10.7.4.3 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.

10.8 TRANSIT CENTRES

Refer to the City of Edmonton Transit Center Guidelines for information on Transit Centre design.

10.9 UTILITY AND STANDALONE SERVICE BUILDINGS

Utility Complexes 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 needed. Where Utility Complex buildings are located within an urban context, the design accommodates 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. Utility Complexes 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 Station design, some utility rooms may be required to be 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 to function as stand-alone Ancillary Facilities, the basic design requirements are outlined below.

10.9.1 Traction Power Substation

10.9.1.1 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 must be approximately 12 m x 12 m, while standalone TPSS are to be approximately 12 m x 16 m.
The TP room must have two man doors and one 3 m x 3 m equipment overhead door. Painted or sealed floors must be provided, and the floor must be level within +/- 1 mm over 1m. 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 must be provided for maintenance and operations with autodialer system functions, and a 15-minute self-contained, gravity-fed eyewash station and an accompanying first aid kit must be provided.

The Designer must coordinate the locations where PVC conduits will pass through the 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.

A clean agent fire suppression system is required in manned facilities. When the 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 equal the same fire resistance rating required for the Signals and communications, or data rooms or the Designer must demonstrate that the proposed rating for the required fire separations does not negatively impact either room with respect to their fire rating.

10.9.1.2 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 building for access to the ROW TP duct banks. An additional, separate manhole is required 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 are to be provided at each TPSS or Utility Complex. Space must be allocated in the Utility Complex yard for an EPCOR switch cubicle and Station service transformer with appropriate clearance and access.

10.9.1.3 Mechanical Requirements
TPSS rooms require 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. The HVAC system must be interlocked with ventilation fans through the building control system. 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 6, Traction Power for ambient temperature requirements.

10.9.1.4 Electrical Requirements
Room lighting must be ceiling mounted, LED fixtures which are to be located to not interfere with the TPSS equipment. Refer to Chapter 11, Electrical, for further information. The TPSS room must be equipped with a dual technology ceiling mount occupancy sensor. The sensor is to remain on for 20 minutes after last activity on the sensor. Based on the size and equipment in the room, multiple sensors may be required.
Exterior light fixtures must be located near each man door and battery powered emergency lighting to meet ABC must be provided.

Loads within the TPSS room must be serviced from a branch circuit panel located within the room. Emergency power trip stations must be located at both man doors to be included in the TP design. Refer to Chapter 6, Traction Power.

Electrical outlets must be provided as per ABC. Fire alarm devices such as smoke detectors and horn/strobes must be placed in accordance with CAN/ULC S-524 [39] and coordinated with TPSS equipment. Final locations must allow for easy maintenance and testing.

10.9.1.5 Grounding
Refer to Chapter 11, Electrical and Chapter 13, Corrosion and Stray Current for grounding details.

10.9.2 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.

10.9.2.1 Finish Requirements
Painted or sealed floors 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.

10.9.2.2 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 occupancy sensor. The sensor is to remain on for 20 mins after last activity on the sensor. Based on the size and equipment in the room, multiple sensors may be required. Battery powered emergency lighting must be provided to meet ABC.

Loads within the room must be serviced from a branch circuit panel located within the room. Fire alarm devices such as smoke detectors and horn/strobes must be placed in accordance with CAN/ULC S-524 and coordinated with the equipment within the room. Final locations must allow for easy maintenance and testing. Refer to Chapter 11, Electrical for further details.

10.9.2.3 Communications & Security Requirements
A clean agent fire suppression system is required in all utility rooms. Clean agent fire suppression systems may be contained within the rooms they are meant to serve. Refer to the manufacturer’s specifications for system requirements.

Card access must be provided at all entry points to 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.
10.9.2.4 Specific Requirements for Communications/Server/Data Rooms
Communication service rooms must be designed to accommodate CCTV and PA racks, telephone system backboards, 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. A copy of the ETS Data Centre Report can be provided by the Engineer.

A clean agent fire suppression system is required. Clean agent fire suppression systems can be contained within the rooms they are meant to serve. Refer to the manufacturer’s specifications for system requirements.

The mechanical system must be designed to limit dust ingress by maintaining positive pressure and/or filtering all air entering the room. Refer to Chapter 12, Mechanical for system requirements. The Designer must confirm all equipment ventilation requirements with the Engineer and the Operator.

10.9.2.5 Specific Requirements for Signals Rooms
Signals rooms must be approximately 6 x 7 m (42 m²) 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 clean agent fire suppression system is required in Signals rooms.

10.9.2.6 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.

10.9.2.7 Specific Requirements for Electrical Rooms
Electrical rooms must be approximately 10 x 5 m (50 m²). For smaller Urban Style Stations, on Platform electrical rooms are generally not feasible. Instead, Power Distribution Centers (PDC) near Stations provide the power feeds to marshalling cabinets on Platforms. Refer to Chapter 11, Electrical.

Where a marshalling cabinet is not sufficient to provide the electrical requirements for a particular Station, an electrical room may be required.

The Uninterruptable Power Supply (UPS) for the facility is to be located within the electrical room with sub-panels in the communications room and Signals room for local UPS loads. Main 600V and 208V distribution boards for the facility are to be located within the electrical room. Step down transformers from 600V to 120/208V are to be located within the electrical room. Any auxiliary fire alarm equipment must be located in the electrical room.

10.10 PARK AND RIDE FACILITIES

The City of Edmonton Park and Ride Guidelines 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 should 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 should be read in conjunction with the City of Edmonton’s Park and Ride Guidelines [12].

10.10.1 Access & Circulation
Parking spaces and traffic aisles should be designed to allow for easy maneuverability of vehicles. The type of circulation system for the design vehicle dimensions and loads should be evaluated by the Designer in conjunction with the Engineer. The design vehicle and 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 sole means of pedestrian access to the Platforms. If warranted by high anticipated pedestrian and vehicle volumes, pedestrian activated flashers and dedicated lighting of crossings may be required.

Obstructions to sight lines at entrances and exits 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. 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 are acceptable. These pedestrian sidewalks must be clearly marked and meet the requirements of the current Design and Construction Standards Chapter 8 [40].

Some fencing types can act as a barrier to the integration of the parking facility with adjacent neighbourhoods and can negatively impact walk up ridership. Confirm fencing requirements in consultation with the Engineer.

For parking structures, at least one stairwell should be located adjacent to each elevator. Elevators should be located in the direction of the walking Patron’s destination.

10.10.1.1 Stall and Aisle Layout and Configuration
Parking lot and structure stall and aisle dimensions must meet the minimum requirements described in the ABC, the City’s Access Design Guidelines [25], and City of Edmonton Bylaw 12800 [5].

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. A one way four bay side-by-side ramped Design for vehicular circulation is preferred in parking structures.

Drive aisles should be aligned for convenient pedestrian movement toward a Station or transit facility. Dead end aisles should not be used.

Parking of over-height vehicles in enclosed parking structures should be limited to the ground floor level.
10.10.2 Parking Structures & Surface Lots

10.10.2.1 Classification
Parking structures must be designed for a 75-year service life and are classified as Group F, Division 3 structures in the ABC. Parking structures should be designed in accordance with the ABC Section 3.2.2.90, such that no fire protection and mechanical ventilation systems are required.

10.10.2.2 Entrance/Exit Lanes
Three entrance/exit lanes must be provided at each entrance/exit with a reversible centre lane to accommodate fluctuations during morning and evening peak hourly flows.

10.10.2.3 Vehicular Ramps
Special transition ramps are required whenever the change in slope at ramps is greater than 8%. The transition ramp must have a minimum length of 3.7 m and have a slope of half the transition.

10.10.2.4 Overhead Clearance
Overhead clearance of 2.75 m or greater should be provided throughout the facility and clearance for maintenance and tow trucks to all levels must be provided. Access by emergency vehicles should also be considered in the Design. Vehicle clearance is most critical at ramp transitions and must be checked against the allowable overhead clearances. Headache bars must be provided at all entrances/exits and at any change in vertical clearance throughout the parking structure.

10.10.2.5 Architectural Finishes
The interior of a parking structure must be painted to optimize lighting uniformity, eliminate glare, and improve energy efficiency. White is preferred on all walls, deck soffits, and ceilings including stairways other than wall space that is required for pedestrian or vehicular wayfinding symbols and graphics. For dust control, all service room walls and ceiling surfaces should be sealed or painted white. Refer to Section 10.11 for Material and Finish Requirements.

10.10.2.6 Utility Requirements
Parking structures may require rooms or dedicated areas to house staff, equipment, and related building systems. The specific requirements for service rooms must be determined in discussion with the Engineer.

A water system must be provided for regular cleaning and maintenance. Hose bibs or other water outlets must be provided evenly around the structure and be tamper resistant. This system must be accessible, reliable, provide equal pressure through the structure, and be drainable /closeable in the winter unless the system is heated and insulated.

Drainage analysis and design must be done in accordance with the City Design and Construction Standards, Volume 3, Drainage and the processes identified in Chapter 16, Utilities and Drainage.

10.10.2.7 Structural Requirements
Conduit or piping for electrical, communications or mechanical systems must not be imbedded in the superstructure. Loading allowances must consider snow removal equipment, and snow piling, including the provision for snow removal by means of a snow chute.

The structure must meet the requirements of CAN/CSA S413 [19] Parking Structures, and the equivalent minimum levels of corrosion protection that are given in Table 1 of CAN/CSA S413. Measures must be provided to minimize and control cracking in all concrete work.
Concrete slab surfaces must be designed to prevent stormwater at design peak flow from spreading a horizontal distance greater than 610 mm from the face of any curbs, walls, or other vertical barriers. The design must prevent stormwater from flowing into stairwell and elevator openings and should limit the ingress of precipitation into the interior of the structure, where possible.

Speed bumps at appropriate locations should be provided to help control vehicle speeds in parking lots and structures.

Refer to Chapter 9, Structures, for structural system design requirements.

10.10.2.8 Maintenance and Operation Considerations
The Design must minimize joints and connections in slabs and pavement to avoid high maintenance locations. All devices should be vandal resistant and corrosion resistant, constructed out of 316L stainless steel, galvanized steel, plastics, or coated to prevent early deterioration.

A waterproof membrane coating system must be placed on the floor to provide protection and prevent delamination. Locations likely to attract roosting or nesting of birds should be minimized. The Designer must consider the use of bird deterrent devices at these locations.

The Designer must coordinate with the Engineer in the development of an O&M plan.

10.10.2.9 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 CSDCS, Volume 2, Roadways.

10.10.2.10 Landscaping
The total area required for landscaping and screening must meet the requirements of the City Zoning Bylaw 12800 [5]. The landscaping design should be done in accordance with the principles stated in Chapter 14, Urban Integration and CSDCS, Volume 5, Landscaping.

10.10.2.11 Safety & Security
Security of Patrons in parking facilities is of paramount importance. The Designer must refer to Chapter 15, Safety and Security and Edmonton’s City Bylaw 12800 for safety and security requirements.

10.10.2.12 Signage
All signage must be designed in accordance with the LRT Graphic Standards Manual. All markings and graphics should be clearly visible, simple, free from clutter, and easily read.

Exterior Park and Ride identification signs must be visible to passing motorists. Each parking facility entrance must include customer information signage displaying operational hours.

In parking structures, signage, graphics, and pavement markings must be provided to assist and direct pedestrian flow to a point of egress including both stairways and elevators. Signage must be located at all decision points to direct drivers to available parking and to exits to promote efficient circulation.

Signs that are critical to the operation of the parking facility must be illuminated during night-time hours.

Signs must be Ultra-Violet (UV) resistant and non-corrodimg.
10.10.2.13 Graphics, Painting, and Pavement Markings
Floor levels, stairwells, and elevator lobbies should be clearly labeled using numbers, color codes, and/or symbols. Bright background colors should be used to enhance the impression of safety and security in parking structures.

All Barrier-Free Accessible stalls must be labelled as defined in the ABC and the Alberta Barrier-Free Design Guide.

10.11 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 others. 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; and Volume 2 Technical Guidelines.

10.11.1 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.

10.11.2 Maintenance Objectives

10.11.2.1 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.

10.11.2.2 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.

10.11.2.3 Design for Maintainability and Replacement
All materials and finishes should be durable and non-toxic and require less frequent maintenance using less potable water, 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.
10.11.3 Performance Standards

10.11.3.1 Durability
The Designer must refer to CSA S478-95 Guideline on Durability in Buildings [18], 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.

Building materials and finishes that are within reach of Patrons (less than 2500 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 (including 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.

10.11.3.2 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.

10.11.3.3 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 (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, light-reflecting, and 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.

**10.11.3.4 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 prevent sound trespass into adjacent spaces, buildings and land uses.

**10.11.3.5 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 [41]; 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 [22].
## APPENDIX 10A – RISK ASSESSMENT CRITERIA FOR PLACEMENT OF GARBAGE/RECYCLING RECEPTACLES

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<th>Description</th>
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<tr>
<td>Pedestrian bottlenecks</td>
<td>Stairways/escalators</td>
<td>X</td>
<td></td>
<td>See Note 1</td>
</tr>
<tr>
<td>Location of critical structural elements in underground Stations</td>
<td>Columns</td>
<td>X</td>
<td></td>
<td>Major impact of structural failure</td>
</tr>
<tr>
<td>Location of critical structural elements in surface Stations</td>
<td>Load bearing walls</td>
<td>X</td>
<td></td>
<td>Major impact of structural failure</td>
</tr>
<tr>
<td>Walkways</td>
<td>Hallways</td>
<td>X</td>
<td></td>
<td>See Note 1</td>
</tr>
<tr>
<td>Glass</td>
<td>Glass enclosures</td>
<td>X</td>
<td></td>
<td>Produces significant amounts of shrapnel</td>
</tr>
<tr>
<td>Glass</td>
<td>Small glass barriers</td>
<td>X</td>
<td></td>
<td>Produces limited amounts of shrapnel</td>
</tr>
<tr>
<td>Enclosed spaces</td>
<td>Alcoves/vestibules</td>
<td>X</td>
<td></td>
<td>Receptacle not visible to pedestrians; poor blast dispersion</td>
</tr>
<tr>
<td>Ceiling height</td>
<td></td>
<td>X</td>
<td></td>
<td>See Note 1</td>
</tr>
<tr>
<td>Utilities</td>
<td>HVAC</td>
<td>X</td>
<td></td>
<td>Limited potential for secondary effects</td>
</tr>
<tr>
<td>Smoke fans</td>
<td>X</td>
<td></td>
<td></td>
<td>Critical to evacuating smoke</td>
</tr>
<tr>
<td>Electrical</td>
<td>X</td>
<td></td>
<td></td>
<td>Limited potential for secondary effects</td>
</tr>
<tr>
<td>Communications</td>
<td>X</td>
<td></td>
<td></td>
<td>Incident reporting/emergency response</td>
</tr>
<tr>
<td>Gas mains</td>
<td>X</td>
<td></td>
<td></td>
<td>Impact of secondary explosion is major</td>
</tr>
<tr>
<td>Gas connections</td>
<td>X</td>
<td></td>
<td></td>
<td>Impact of secondary explosion is less</td>
</tr>
<tr>
<td>Fire-life safety systems</td>
<td>X</td>
<td></td>
<td></td>
<td>Limited potential for secondary effects</td>
</tr>
<tr>
<td>High pressure steam</td>
<td>X</td>
<td></td>
<td></td>
<td>Potential for secondary effects</td>
</tr>
<tr>
<td>Signal room/substation</td>
<td>X</td>
<td></td>
<td></td>
<td>Required to maintain power/Train control</td>
</tr>
<tr>
<td>Flammable and toxic materials</td>
<td>X</td>
<td></td>
<td></td>
<td>Minimal storage of materials in LRT Stations</td>
</tr>
</tbody>
</table>

**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.
FIGURE 10.3
PLATFORM TACTILE WARNING STRIP

CHAPTER 10
STATIONS AND ANCILLARY FACILITIES
FIGURE 10.5
FARE VALIDATOR STAND

NOTES:
VALIDATOR STAND MATERIAL: BRUSHED STAINLESS STEEL
VALIDATOR TO BE SHROUDED IF LOCATED IN AN UNCOVERED PORTION OF THE PLATFORM
FIGURE 10.7
BIKE STAND
REFERENCES


[38] City of Edmonton, "Bylaw 14600 Community Standards Bylaw," City of Edmonton, Edmonton, AB, 2019.


CHAPTER 11

Electrical
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11.0 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
- Utility Complexes
- Traction Power Substations (TPSS)
- Maintenance facilities
- Parking facilities

This chapter also includes guidelines for:

- Lighting
- Fire alarm and detection
- Grounding and bonding
- 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:

- Alberta Building Code (ABC) [1]
- Alberta Electrical and Communication Utility Code (AECUC)
- Alberta Electrical Code Regulation (AECR) [2]
- Alberta Safety Code Act (ASCA) [3]
- Canadian Electrical Code (CEC) [4]
- Lighting Handbook (IES) [5]
- National Building Code of Canada (NBC) [6]
- Occupational Health and Safety Act (OHSA) [7]

Reference guidelines for the Design include:

- City of Edmonton Design Guide for a Safer City [8]
- EPCOR Customer Connection Guide [9]
- LEED Green Building Rating System [10]
- NFPA 70 National Electrical Code [12]
- Road and Walkway Lighting Manual [13]
- TCRP Report on Passenger Loading
- Transportation Services Electrical Services Plan (TESP)

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 kVAC 3-phase utility power is typically stepped down to 600 VAC for distribution by the LRT electrical system. At the load location, the power is further stepped down to 120/208 V or 240 V for use by the end devices.

The way power is distributed and the type of power provided depends on the requirements in the area. Where multiple systems are required, the Engineer’s preference is to have a joint use Utility Complex placed near the associated Station. The Utility Complex houses the electrical room that services the communications, Signals, TP, Medium Voltage (MV), and mechanical rooms in the building. A typical Utility Complex equipment layout is shown in Appendix 11A Figure 11.1. The electrical room also services the nearby Station and the ROW electrical distribution system.

For maintenance facilities or below grade Stations, electrical rooms must be incorporated into the facility building or below grade structure.

11.2.1 Electrical Loads

11.2.1.1 Normal Power (Utility)

Normal power is typically supplied from the utility provider to downstream systems with 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:

- Non-emergency lighting
11.6 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 considered normal power backed up by a standby source such as an alternate utility feed or an onsite 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:

- 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

11.2.1.3 Critical Power (Utility, Standby, and UPS/Rectifier/Batteries)
Critical power is essential power further backed up by an Uninterruptable Power Supply (UPS), rectifier and/or batteries. The loads that require critical power are those that cannot withstand even a momentary outage. Typical loads connected to the critical power include:

- Communications equipment
  - Network infrastructure
  - Public Address/Variable Message Sign (PA/VMS) systems
  - Closed Circuit Television (CCTV) and security surveillance
  - Smart Fare Vending Machines (SFVM) and validators
  - Mobile radio systems
  - Card access systems
  - Emergency phones
  - Building Management Systems (BMS)

- Signal equipment, subsystems, and subcomponents
- TPSS protection, control, and communications
- Station emergency lighting and signage
- Tunnel emergency lighting and signage
- Fire alarm systems

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 Utility Complex or placed closer to the equipment such as 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
In the event 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.

If two utility feeds with independent transformers are provided with an automatic transfer scheme, then a 2 hour UPS rated for peak operation is required. The automatic transfer scheme must include provisions for connecting to the communications network and providing status and alarms on BMS.

If an onsite generator is available with its own transformer then a 2 hour UPS rated for peak operation is required. The generator set needs to include provisions for connecting to the communications network and providing status and alarms on BMS. Refer to Chapter 12, Mechanical for points to be monitored on the BMS.

If no secondary backup is available, then 8 hours of UPS backup is required.

For Urban Style Stations, redundancy can be provided by a plug for a portable generator set provided the capacity of the portable generator is adequate to supply the critical services of emergency lights, CCTV, fire alarms, PA, Ticket Vending Machines (TVM), BMS, Smart Fare equipment, and Signal equipment.

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 is not permitted for use in supplying power to essential and critical power loads.

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 their system covered 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 Utility Complexes to the LRT ROW using the underground duct bank system and/or a series of raceways.

11.2.3.1 Power Distribution Centres
Weatherproof, vandalism resistant, environmentally controlled PDC must be installed at strategic locations along the ROW to provide localized power to the various system components and Stations. The PDC 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. PDC must be located near the area being served and must be easily accessible for service.

11.2.3.2 Marshalling Cabinets
Weatherproof, vandalism resistant, environmentally controlled marshalling cabinets must be installed at Urban Style Stations to provide localized power and low-tension system distribution to the various system components. Where practicable, marshalling cabinets must blend into the environment but must be easily accessible for service. Refer to Appendix 11A Figures 11.8 and 11.9 for details. The system must be designed to achieve arc rating of 4 cal/cm² or less. Coordination and arc flash studies must be completed to confirm this requirement. 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. It can also be used for heat trace systems, independent UPS units, power distribution units or any other 120 V and above systems.

Low-tension Marshalling Cabinet
Low-tension marshalling cabinets must be serviced with single mode fiber from the nearest fiber main and will house fiber splitters, fiber patch panels, PA systems, low voltage lighting systems, BMS, and any other below 90 V system. The intent is for all field devices to be fed with fiber in the field with media converters mounted near each field device.

11.2.3.3 Signal Bungalows
Signal bungalows house the necessary equipment required to power crossing gates, Signal devices, and track switches. The Signal bungalows will be powered from the ROW PDCs with 120/240 V AC. The PDC that powers the bungalows will be fed essential power from the Utility Complex electrical room. Refer to Chapter 7, Signals for additional bungalow details.

11.2.3.4 Maintenance Receptacles
Weatherproof, vandalism resistant 15 A/120 V duplex receptacles must be installed at 30 m intervals through tunnel sections, at tunnel track switches, and along Platforms. Receptacles are also required near service points, including:

- Signaling termination cabinets
- Emergency phone locations
- LRT ROW phone locations
- Switch blowers
- PDC locations

To deter loitering, the Design must show twist lock electrical receptacles at locations that are easily accessible by the public.

11.2.4 Design Considerations

11.2.4.1 Demand Factors
During design, demand factors must be used to establish the loading requirements of the electrical system equipment. The following are some typical load factors that must be applied during design:

- 1.0 for lighting, Signal and communications infrastructure, and escalators
11.2.4.2 Spare Capacity
The electrical system must be designed for the known load requirements with an additional 30% load capacity for future expansion. Distribution panels must reserve 25% of the panel physical space for future circuit requirements.

11.2.4.3 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.

11.2.5 Studies and Calculations
The following 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

11.2.5.1 Short Circuit and Fault Analysis
A short circuit and fault analysis must be performed to ensure 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 ensure 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.

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.

11.2.5.5 Lighting Level Study
A lighting level study must be performed to confirm that adequate 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. Refer to Chapter 12, Mechanical for specific requirements.

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 possible when used in similar applications throughout the LRT System

All materials proposed for use 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).

11.3.1.2 Spare Parts
During Design, the Designer must define 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.

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.

All enclosures located outdoors, in a tunnel or trench, or on a Grade Separated structure 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. Matte or flat finish paint is not acceptable.

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 and pullboxes must be as follows:

**Table 11.1 System Elements Colour**

<table>
<thead>
<tr>
<th>Application</th>
<th>Colour</th>
<th>Colour Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 750 V</td>
<td>Grey</td>
<td>RAL 7035</td>
</tr>
<tr>
<td>347/600 V</td>
<td>Sand</td>
<td>CIL-BH-355-7</td>
</tr>
<tr>
<td>120/208 V</td>
<td>Grey</td>
<td>CI-BH-94222</td>
</tr>
<tr>
<td>Fire Alarm</td>
<td>Red</td>
<td>CI-BH-94351</td>
</tr>
<tr>
<td>Telephone/Data</td>
<td>Grey</td>
<td>CI-BH-94222</td>
</tr>
<tr>
<td>PA/VMS</td>
<td>Blue</td>
<td></td>
</tr>
<tr>
<td>CCTV</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>Low Voltage Switching</td>
<td>Black Enamel</td>
<td></td>
</tr>
</tbody>
</table>

Emergency power pullboxes must be clearly labeled with 25 mm “EM” stenciled red letters over the system colour.

Transformer enclosures must be finished in accordance with primary voltage colour as outlined above.

### 11.3.2.2 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 in accordance with the following:

**Table 11.2 Conductor Colour**

<table>
<thead>
<tr>
<th>Application</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Bonding Conductor</td>
<td>Grey</td>
</tr>
<tr>
<td>Identified Conductor (Neutral)</td>
<td>Sand</td>
</tr>
<tr>
<td>120/208 V Phase Wires</td>
<td>Grey</td>
</tr>
<tr>
<td>347/600 V Phase Wires</td>
<td>Red</td>
</tr>
<tr>
<td>Data Cabling</td>
<td>Blue</td>
</tr>
<tr>
<td>Voice Cabling</td>
<td>Blue</td>
</tr>
</tbody>
</table>

At all distribution centres, pullboxes, and wireways, feeder conductors of each feeder group must be neatly laced or clipped into a feeder group.

Fire alarm system control cable suitable for addressable fire alarm systems must be used and installed in conduit systems.
11.3.2.3 Nametags

Nameplate schedules must be prepared and issued to the Engineer for review and acceptance. Final markings, as determined in consultation with the Engineer, must be placed on the drawings for implementation during construction.

Main Distribution Panels (MDP), Central Distribution Panels (CDP), power panels, lighting panels, disconnect switches, starters, contactors, motor control centres, terminal cabinets, junction boxes, On/Off switches, and transformers must be clearly identified by permanent labels in accordance with the following requirements:

- Nametags must be 3-layer laminated plastic, black/white/black with etched white lettering on black background where called for on the drawings or in the specifications
- Letters on nametags must be a minimum of 9.5 mm in height
- All nametags must be mechanically fastened with either machine screws or rivets, in addition to adhesive backing

Terminal strips must be identified in terminal cabinets for control wiring, CCTV distribution, intercommunication, sound, telephone, fire alarm, and timing, using typed lists.

Communication vaults, catenary power vaults, and utility power vaults must be clearly identified as shown in the Design.

A preliminary cable and conduit schedule must be developed during design. Specifications must require Contractors to identify each cable and conduit with their origin and destination at either end.

Panels, along with their rated voltage, must be as shown in the Design. Where panels are located in areas other than electrical rooms, nametags must be clearly identified as shown in the Design.

Transformers along with their capacity, primary voltage, and secondary voltage must be clearly identified as shown in the Design.

For disconnect switches, starters, and contactors, the controlled equipment and rated voltage must be indicated.

The areas being served by on/off switches must be indicated.

Terminal cabinets and pull-box systems voltages must be indicated.

Distribution centres must be identified as indicated in the Design and must show the main voltage or voltages if more than one is used.

Motor control centres must be identified as shown on the Design drawings and must show main voltage or voltages if more than one is used.

11.4 EQUIPMENT

11.4.1 Motors

Motor supply voltage requirements are based on the power rating as follows:

- 0.56 kW or larger must be supplied by 208 V 3-phase or 600 V 3-phase if available
• 0.37 kW or smaller must be supplied by 120V 1-phase.

In addition, motors used with variable speed drive applications must be inverter duty rated and all motors must be high efficiency.

### 11.4.2 Transformers
Transformers must be located away from any critical low noise areas and must be mounted on neoprene-steel-neoprene vibration isolation pads with flexible conduit connections. In addition, transformers must be dry type construction, TP1 “Energy Star” and C802.2 compliant or rated, and include core and coil temperature gauges and alarms for MV rated transformers.

### 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 complete with a bonding lug. In general, the enclosures must be of type EEMAC 1.

### 11.4.4 Manual Transfer Switch
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 emergency 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
- 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 onsite backup power is required. In general, the requirement for a permanent emergency generator must be reviewed on a location basis at the outset of Design.
11.4.6.1 Standby Generators
Standby generators must comply with the latest CSA-C282 [14] latest standard for emergency electrical power supply in buildings.

Generators and day tanks must be located in a dedicated room within a Utility Complex 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.

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.

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.

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 a portable generator to provide emergency power. A manual transfer system must be provided with a weather-proof receptacle compatible with the Operator’s existing portable generators. The transfer system must incorporate over-current protection and reverse rotation protection.

The emergency power tie-in assembly including generator receptacle must be located adjacent to the Platform 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 Uninterruptable Power Supply
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, back-up and distribution for miscellaneous emergency and critical loads, including Non-Vital and Vital electrical 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:

- Back-up utility or generator supply available – UPS rated for two hours at 100% load
- No back-up 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.

11.4.9 Distribution Panelboards
Panelboards must be located in each service room within Utility Complex 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, except in marshalling cabinets. All panelboards on one site must be from one manufacturer. Circuit breakers in panelboards must be pre-installed before shipment.

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 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 designates an open breaker. Breakers must be lock-on devices for fire alarm and security system.

### 11.4.10 Maintenance Bypass Switch

For larger UPS installations, an automated 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.

### 11.4.11 Rectiverter

For communications systems the preferred method of supplying and providing back-up power to subsystems and subcomponents is through a rectiverter. These systems must be designed to be capable of operating in the three different modes, as an inverter, rectifier, and rectiverter with seamless transitions between the modes to ensure power supply to the critical devices is not lost. A battery system must be included in the Design to allow the rectiverter to operate in the inverter mode when utility supply from the critical panel is lost. The rectiverter at minimum must provide line conditioning for operation in AC input to AC output mode, seamless switch-over to DC source where the AC output never experiences a transient or interruption, and seamless reconnection to AC input once the system determines the main has returned to a normal range and the AC output is in phase with the input.

The rectiverter must also provide surge overvoltage protection to protect internal semiconductor switches. This does not eliminate the requirement for separate surge protective devices designed to protect the various electrical systems within the Utility Complex from external lightning strikes.

Backfeed protection for rectivers to mitigate the risk of potential being present on the AC input terminals during interruption of the normal AC input power must be provided.

To further improve the system redundancy, the critical panel feeding the rectiverter must be supplied by two interlocked breakers, one from each the essential and normal panels. An example is shown in Appendix 11A Figure 11.2.

For Utility Complex locations where a data centre is required dual rectivers must be provided and each must have separate and independent upstream supplies. The level of redundancy required for locations with a data centre is significantly increased, as shown in Appendix 11A Figure 11.3. The rectivers will...
be accompanied by an auto transfer switch to provide uninterrupted supply of power to communication system critical load during a single rectifier outage.

### 11.4.12 Rectifier/Battery Charger
Chargers must be specifically designed to operate with 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.

### 11.4.13 Batteries
Batteries must be constructed with an electrolytic material and type 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. The Designer must size each battery string for 90 minutes at 100% of the UPS rated load with a capacity exceeding 80% throughout the specified design life of the batteries. Manual switching must be provided so each UPS may connect to either or both battery strings.

### 11.5 ELECTRICAL HEAT TRACE SYSTEMS

#### 11.5.1 General Requirements
Heat tracing is to be provided for the following elements when 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 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 possible. The contactor and coil assembly must be contained in an enclosure housed within the marshalling cabinet.

#### 11.5.2 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.
11.5.3 Power Services
The heat tracing system must be supplied from panelboards located at the nearest LRT service location, such as a Station or tunnel portal.

All power connections, in feed and junction boxes, must be appropriate for their location. If located outdoors or in tunnels they must be watertight enclosures appropriate for accepting either in-slab or surface conduit entry.

11.5.4 Snow and Ice Melt Systems
Exterior stairs and ramps must be protected from snow and ice accumulation by providing either roof cover or snow melting devices. Snow melting systems must be provided with remote controls for each stairway or ramp.

Mechanical (glycol) snow melting, where it is cost effective, practicable, and applicable may be considered as an option to concrete embedded electric snow melt systems.

The Designer must review the required performance of snow melt systems proposed for the LRT System with the Engineer at the outset of Design preparation.

11.6 FIRE ALARM AND DETECTION

Fire alarm detection systems are required for all enclosed buildings such as Utility Complexes, buildings with fire suppression systems, and Stations with enclosed underground Platforms as well as tunnel sections requiring ventilation. A fire alarm system will also be required 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.

Consideration must be given to a method of preventing fire doors from closing during routine generator testing. The routine generator test momentarily shuts off the power and is identified as a power failure in the system, which activates preventative measures such as the closing of the doors.
Fire alarm speakers and strobes must be used for audible and visual alarms in all areas with public access and within a Utility Complex. 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.

High significance or critical rooms such as main server/data centres may require very early detection systems (VESDA) and/or 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 crawl spaces are proposed, the current ABC [1] 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.

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 future expansion of retail space or additional services.

Manual pull-stations in public areas must have covers to prevent vandalism and misuse.

The Design must include an exterior audible and visual indicator at each building.

All fire detectors, unless disqualified by the environment in which they are placed, must be of the addressable type.

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.

11.7 LIGHTING

The lighting guidelines presented in this section outline the functional requirements for site areas, pedways, Stations and related service areas, tunnels, portals, Open Trackway, and parking facilities including Park and Ride lots.

Conformance to these guidelines is necessary to ensure lighting levels are adequate and the intended quality, convenience, efficiency, and system safety requirements are provided. Ease of maintenance must be a primary consideration in the selection of lighting systems and devices.

11.7.1 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, mounting remote ballasts and drivers in an accessible location should be considered. 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 luminaires that are not accessible to the public.

Lighting design principles for Stations are presented in Chapter 10, Stations and Ancillary Facilities. These principles can also be applied to other components of the LRT System that require lighting.


### 11.7.2 Performance Standards

All luminaires must be commercial/industrial grade, and all Platform, tunnel, underpass, and exterior luminaires within the LRT ROW must be IP 66 rated.

The average to minimum uniformity ratio for interior lighting must not exceed 3:1. For exterior path and roadway lighting, the minimum uniformity ratio must be 6:1.

The colour temperature (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.

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.

### 11.7.3 Standard Lighting Elements/Fixtures

#### 11.7.3.1 Lighting Sources

LED lighting should be used for all lighting Design, however there may be locations where other lighting sources may be considered. The Designer must provide recommendations for lighting sources.

Guards or vandal resistant luminaires must be used to protect lighting in areas where there is 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 on the Stations and Utility Complex 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.
Consideration must be given to protecting overhead lighting in public areas from falling through the use of safety chains fastened to the roof or ceiling. Some of the factors to consider in determining if a chain is required include the type and location of the luminaire, and the potential for vibration.

11.7.3.2 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.

11.7.4 Illumination Levels
In general, minimum lighting levels (except where otherwise noted) must be maintained 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 as a result of the experience gained by the Operator over the LRT operating period in Edmonton. Higher levels in public circulation areas are preferred. Illumination levels should also be reviewed with the Engineer and Operator in conjunction with Corporate Security and CPTED [16] reviews for each site.

Table 11.3 Interior Spaces

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Minimum Lux</th>
<th>Minimum Emergency Egress Lighting as per ABC</th>
<th>Average Minimum Lux under Normal power outage (on Generator or UPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Circulation Areas1</td>
<td>350</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Platforms (Above &amp; At-Grade)</td>
<td>300</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Platforms (Below Grade)</td>
<td>350</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Heated Shelters</td>
<td>350</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Interior Stairs, Ramps, Escalators</td>
<td>350</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Elevators Entrance &amp; Interiors2</td>
<td>350</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Service Rooms3</td>
<td>500</td>
<td>10</td>
<td>250</td>
</tr>
<tr>
<td>Washrooms</td>
<td>350</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Crawl Spaces4</td>
<td>150</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>Utility Complex Corridors</td>
<td>150</td>
<td>10</td>
<td>60</td>
</tr>
</tbody>
</table>

Notes:
1. Public circulation areas include passageways, pedways, entranceways, mezzanine levels, and ticketing areas
2. Coordinate with elevator supplier
3. Rooms such as TPSS, communications, Signals, electrical, mechanical, high voltage, generator, outside service provider room
4. Luminaires must be damp location rated

11.7.4.1 Parkade Structures
Lighting levels for parkade structures are to be designed as per the IESNA RP-8-2018 [17]. Refer to Chapter 10, Stations and Ancillary Facilities for further information on design requirements for parkade structures.
### Table 11.4 Exterior Spaces

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Minimum Lux</th>
<th>Minimum Emergency Egress Lighting as per ABC</th>
<th>Average Minimum Lux under Normal power outage&lt;sup&gt;2&lt;/sup&gt; (on Generator or UPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairs&lt;sup&gt;3&lt;/sup&gt;</td>
<td>200</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Exterior Walkways/Ramps connected to Stations&lt;sup&gt;3&lt;/sup&gt;</td>
<td>50</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Private Vehicle/Taxi Drop-off</td>
<td>25</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Plaza Areas/Pathways to Stations&lt;sup&gt;3&lt;/sup&gt;</td>
<td>25</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Amenity Areas (bike racks, benches, and other)</td>
<td>25</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Surface Public Parking Lots</td>
<td>25</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Transit Centre Islands</td>
<td>20&lt;sup&gt;1&lt;/sup&gt;</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Entry Man Doors</td>
<td>50</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Exterior Perimeter around Utility Complex Buildings</td>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Utility Complex Parking areas</td>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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

### Table 11.5 Trackway

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Minimum Lux</th>
<th>Minimum Emergency Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Trackways:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Barrier&lt;sup&gt;2&lt;/sup&gt;</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Soft Barrier (shrubs, chain and bollard, curb)</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Hard Barrier</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LRT ROW Equipment Areas&lt;sup&gt;3&lt;/sup&gt;</td>
<td>20</td>
<td>N/A</td>
</tr>
<tr>
<td>Tunnels - Trackway and Emergency Egress</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Walkways (including Catwalks)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Cross-Connections</td>
<td>40</td>
<td>N/A</td>
</tr>
<tr>
<td>Track Switches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade Separation (short underpass) &lt;sup&gt;2&lt;/sup&gt;</td>
<td>20 to 50 nighttime</td>
<td>10</td>
</tr>
</tbody>
</table>
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 [17] and the Transportation Association of Canada (TAC) Guide for the Design of Roadway Lighting [15] 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, Signal bungalows to deter equipment vandalism.

### 11.7.4.2 Tunnel - Portal Transition
Special consideration must be given at tunnel entrances to provide for the transition of lighting levels from daylight to darkness. 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 [17] and the Guide for the Design of Roadway Lighting [15] 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. The table below shows the anticipated transition lengths and lux values.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Distance from Portal</th>
<th>Daytime Lux</th>
<th>Nighttime Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 to 30 m</td>
<td>5000</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>30 to 60 m</td>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>60 to 90 m</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Greater than 90 m</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

For additional guidance the Designer must refer to the IES Lighting Handbook [5]. The Designer must coordinate with the Engineer to verify that the proposed lighting levels are acceptable and appropriate for the application.

### 11.7.5 Lighting Control Systems
Low voltage lighting controls must be operated by a simple relay-based system. If a network system is required, the system must be DALI based. Any other type of low voltage system must be reviewed and approved by the Engineer. Low voltage lighting control must be monitored and controlled by the BMS. Refer to Chapter 12, Mechanical for further details.

Low voltage lighting control panels in a Utility Complex must be located in the electrical room with operable switches in each room. Low voltage lighting control panels on Platforms must be located in a marshalling cabinet.

Motion sensor or timer control is required only in washrooms, janitorial, and storage rooms.

Open At-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).
11.7.6 Lighting Energy Conservation Measures
As per City Policy C532, LEED protocol [18] must be utilized where applicable and practicable. Innovations to reach acceptable lighting levels while lowering operating costs are encouraged subject to the Engineer’s review and approval.

11.7.7 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.

Emergency lighting sources must be LED to provide the required instant restrike following a power failure.

11.7.7.1 Power Supply Sources
If a utility back up to the normal feed is available, then all lighting in a Utility Complex or Station must be connected to the normal power with redundant backup. If the primary normal power is compromised, then the redundant power feed must pick up the entire load.

If a permanent or portable generator is available with a redundant power feed, then a minimum 40% of the lighting in a Utility Complex or Station must be connected to the generator. Some lights must be circuited to the normal power circuit and the remaining lights must be connected to the generator. This arrangement must provide the required illumination in all areas if utility feeds in the area are compromised. The Designer must review this requirement with the Engineer at the outset of design to confirm if 40% illumination is required on the generator or only the minimum 10 lux for egress as per code.

If a redundant utility feed is not available with only a portable generator connected, a UPS must be provided to power the emergency lighting. A minimum 40% of the lighting in a Utility Complex or Station must be connected to the UPS. Some lights must be circuited to the normal power circuit and the remaining lights must be connected to the UPS. This arrangement must provide 40% illumination in all areas if utility feeds in the area are compromised. The Designer must review this requirement with the Engineer at the outset of design to confirm if 40% illumination is required on the generator or only the minimum 10 lux for egress as per code. UPS is preferred over self contained battery packs and must be backed up by a generator when available. The UPS capacity must be sized in accordance with the general guidelines stated above. Where emergency lighting with self contained battery packs is provided, the emergency lighting must not be connected to the UPS system.

11.7.7.2 Emergency Lamp Types
Emergency lighting sources may be LED, incandescent quartz, induction lamp, or fluorescent to provide the required instant restrike following a power failure.

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.

11.7.8 Crew Advisory Lights
Track portions 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 section. Zones may be created based on the overall length of the track within the tunnel or on the structure. 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.

11.8 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 the cubicle unless the cubicle is accessible from the back.

11.8.1 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.

11.8.2 Distribution Equipment Metering

Owner distribution equipment metering is required to allow 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 outages, and future expansion. At minimum, a meter is required at input of the normal utility feed. In addition, the essential panel must be prescribed as a smart panel for monitoring all individual essential loads. Appendix 11A Figure 11.2 identifies these metering points.

The metering devices are to 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.

11.9 GROUNDING AND BONDING

Grounding and bonding ensure that all metallic structures, buildings, cases, and systems equipment are adequately grounded 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.
11.9.1 General

11.9.1.1 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 earth.

11.9.1.2 Connections
Above and below grade ground electrode and grid cable connections must be made with compression type connectors installed with a suitable hydraulic press. Exothermic welding is only to be used where absolutely necessary. Where separation of ground elements is required for testing, bolted/mechanical connections must be used.

11.9.1.3 Inspection Wells
Where access to ground conductors below grade is necessary for testing, a CSA certified inspection well is required. The wells must be strategically placed to avoid damage and must be rated for the location of the well.

11.9.1.4 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 earth. 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.

11.9.1.5 Theft Prevention
Where possible, 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 easy for the Operator.

11.9.1.6 Transformer Grounding
As per CEC, a grounding conductor must be run from the supply distribution centre to the neutral on the secondary of the transformer and to the system grounding bus.

11.9.2 Right-of-Way and Traction Power Grounding (Tunnels or Grade Separations)
Separate grounding systems are required in the tunnels and portals for TP and LRT ROW grounding.

11.9.2.1 Right-of-Way Grounding
The LRT ROW grounding system consists of two continuous copper conductors (ground runners), one per track. The LRT ROW ground runner must run the entire length of the tunnel 1 m above the top of the track. The LRT ROW grounding 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) require bonding 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 miscellaneous metal that is continuous 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 is bonded at 50 m intervals. The bonding of the rebar must follow the recommendations of the Corrosion and Stray Current Study. Refer to Chapter 13, Corrosion and Stray Current.

11.9.2.2 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 require bonding 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.

11.9.3 Right-of-Way and Traction Power Grounding (Open Trackway)
Separate grounding systems are required in the open line for TP and LRT ROW grounding.

11.9.3.1 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 earth. These ground runners are typically installed below the track ballast or structure and routed alongside or above the track drainage system. The ground runners are 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 fallen Overhead Contact System (OCS), the ground runners must be strategically segmented where practicable.

The ground runners are not required to be tied to any of the concrete reinforcing steel unless it is deemed necessary through a corrosion and stray current study. All connections must be made using compression connectors. Ground/bond conductors are not required within the concrete of duct banks.

11.9.3.2 Traction Power Grounding
For TP OCS poles with no positive feeders, only one localized ground grid per pole base is required. For poles with feeders, a second dedicated grid for lightning protection grounding is required. The two ground grids must be separated by at least 2 m. Lighting protection grounding is also typically required 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.
11.9.4 Ground Fault Protection
Ground fault protection must be provided on all major feeders if required by code or if the Designer determines this to be required. The Designer must evaluate the risk of devices being exposed to moisture and water based on their location and the potential impacts to the system to determine if additional ground fault protection is required. The Designer must ensure that proper coordination between downstream overcurrent devices and upstream ground fault protected breakers. Coordination of all electrical overcurrent devices is to be undertaken in accordance with IEEE Buff Book [19].

11.9.5 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 recommended protective techniques and provisions to minimize and mitigate Stray Current corrosion. Refer to Chapter 13, Corrosion and Stray Current for specific design guidelines.

11.10 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 are 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.

11.10.1 Duct Bank Construction General Requirements

11.10.1.1 Duct Bank Construction
Underground duct banks must be constructed of concrete encased conduit type DB2 or equivalent and reinforced with steel. Conduits must be spaced in accordance with the manufacturer’s recommendations. Duct spacers are required to maintain even spacing of ducts.

The main reinforcing steel rebar must be 15M and placed so that the lengths overlap a minimum of 300 mm. The placement of the rebar must be adequate 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 buried installations, and 75mm is preferred. Depending upon the location, additional structural protection 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 and 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.

11.10.1.2 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 the duct bank to the centreline of track is 3000 mm, to permit safe access to vaults. This clearance will depend upon routing constraints such as available property and other design elements in the LRT ROW. Coordination is required with other interfacing Designers and the Engineer to determine the routing of each duct bank.

11.10.1.3 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. Both vary in size and load capacity depending on the application and site-specific conditions. The vaults and boxes 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 light weight high impact aluminum. At certain locations, vaults must have slam lock lids and 90º hold open arms.

Identification labels must be provided on pullbox lids as well as duct assignment inside. Refer to Appendix 11A Figure 11.7 for typical pullbox details. An identification schedule for both conduit and cable must be prepared 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 ensure that the cables in vaults and boxes are neatly racked and take into account entry and exit cable routing when assigning conduits to maximize the efficiency of cable management within a pullbox or vault.

11.10.1.4 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 ensure adequate drainage. Refer to Chapter 16, Utilities and Drainage.

All cable-vaults and pullboxes must be connected to the adjacent track drainage system and incorporate backflow prevention. A dry well system may be considered only if connection to a gravity storm drainage system is not feasible. 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.

11.10.1.5 Branch Ducts
Concrete encased branch ducts for stub points and branch lines should be constructed with the main duct system where possible. All conduits crossing a roadway must be encased in concrete and placed at a depth where damage to the conduits will not occur and the ducts will not influence the performance of the track support system.
11.10.1.6 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.

11.10.1.7 Identification of Ducts, Cable Vaults and Pullboxes
The identification of ducts, cable vaults, pullbox must be system specific and follow the existing standard developed by the Operator. Schedule lists for the ducts, cable vaults, and pullboxes must be developed as part of the Design for review by the Engineer.

11.10.1.8 Separation
If possible, 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 practices.

11.10.1.9 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.

11.10.1.10 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.

11.10.2 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 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 is 12 x 103 mm ducts (refer to Appendix 11A Figure 11.1)
- The maximum straight line spacing between vaults and pullboxes is 200 m
- A maximum of 180° of bends is permitted between pullboxes with 90° bends considered to be communications sweeps with a radius of 11 times 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 utilizing 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 are required for Signals and communications

11.10.3 Traction Power
Positive and negative TP ducts distribute power cables from the TPSS to the OCS and rails. 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 90⁰ bends
• Ducts must be routed with a preferred 3000 mm clearance from the centreline of the tracks
• Any TP ducts crossing the Trackway must cross at 90⁰
• One spare duct must be provided for each positive feeder circuit
• Two spare ducts must be provided for each negative circuit
• All 90⁰ bends must have a minimum bending radius of 900 mm
• Dedicated cable vaults and pullboxes are require for TP and must not be routed within 1500 mm of the centre of track when run in parallel the LRT Trackway

11.10.4 Right-of-Way Electrical
Duct banks and branch ducts are required to house cable providing electrical power to the devices located along the ROW, including:

• Power distribution cabinets
• Marshalling cabinets
• 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, the typical configurations are 2 x 103 mm or 4 x 103 mm ducts, 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

11.10.5 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 versions 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 are based on the cable size being installed or as required by the utility service provider
• Utility cable vaults and pull pits must comply with the utility service provider’s standards
11.10.6 Conduits and Raceways Additional Requirements

11.10.6.1 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, all conduits entering a building must be sealed by a sealing system approved by the Engineer.

11.10.6.2 Fastening Devices
All electrical equipment and systems must be fastened with flush mount internal threaded metallic anchoring systems designed for the specific application.

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.

11.10.6.3 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.

11.10.6.4 Fiberglass Conduit
For TP positive and negative cable installations in below and above 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.

11.10.6.5 Conduit in Slabs
For new installations, conduit should not be placed directly in concrete slabs. If required, this option 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.

11.10.6.6 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 adequate number of nylon pull cords installed.

11.10.6.7 Raceways
Rigid galvanized steel conduit must be used in all exposed raceway installations and in tunnels.

PVC or DB2 conduit may be used in concrete or PVC when located below grade. PVC conduit emerging from grade or from concrete and routing on the surface must be converted to rigid steel for all non-traction power installations. The transition from PVC to rigid steel conduit is achieved through a coupling that is covered in a heat shrink sleeve and taped. The transition must take place before emerging from grade 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 principle raceway within a TPSS with the exception of the DC TP and the MV power. No plastic pipe is to be used within a TPSS. Plastic pipe
emerging within the TPSS is to be converted to either rigid steel, RTRC, or EMT. Metal conduit must be bonded to ground using the correct 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.

**11.10.6.8 Expansion Joints**
Conduits that are prone to the effects of expansion, 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.

**11.11 ELECTRICAL UTILITY COORDINATION**

The Designer should engage the services and input of the utility service provides early and continuously throughout the project. The utility provider’s engineering services personnel are to 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 to the LRT System. Typically, both low and MV utility power is required by the LRT System. The utility service providers have very 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.

**11.12 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.

**11.13 STANDARD RECORD DOCUMENTS**

For standard record documentation requirements refer to Chapter 1, General.
APPENDIX 11A – FIGURES
NOTES:
1. ALL DIMENSIONS ARE APPROXIMATE AND ARE SHOWN IN mm.
2. STATION SERVICE 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 (i.e., NORMAL, CRITICAL, AND ESSENTIAL LOADS).
4. DOORS TO BE SIZED TO ALLOW TRANSFORMERS AND NECESSARY EQUIPMENT TO PASS THROUGH.

FIGURE 11.1
TYPICAL UTILITY COMPLEX ROE EQUIPMENT LAYOUT
NOTES:
1. THE GROUND BELOW AND BACKFILL ON BOTH SIDES OF THE DUCTBANK IS COMPACTED TO PROCTOR LEVEL, DEPENDENT ON SOIL CONDITIONS.
2. 90 mm MINIMUM CONCRETE COVER FOR MAIN REINFORCING BARS.
3. REBAR MINIMUM LAP IS 300 mm, REBAR LAPS ARE STAGGERED.
4. HORIZONTAL POSITION OF REBAR MAINTAINED BY DUCT SPACERS.

FIGURE 11.4
TYPICAL COMMUNICATION DUCTBANK CONFIGURATION

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Date  Revision
NOTES:

1. THE CLOTH BELOW AND BACKFILL ON BOTH SIDES OF THE DUCTBANK IS COMPACTED TO PROCTOR LEVEL DEPENDENT ON SOIL CONDITIONS.
2. 90 mm MINIMUM CONCRETE COVER FOR MAIN REINFORCING BARS.
3. REBAR MINIMUM LAP IS 300 mm... REBAR LAPS ARE STAGGERED.
4. HORIZONTAL POSITION OF REBAR MAINTAINED BY DUCT SPACERS.

FIGURE 11.5
TYPICAL RIGHT OF WAY ELECTRICAL AND TRACTION POWER DUCTBANK CONFIGURATION.
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FIGURE 11.6
TYPICAL MANHOLE DETAILS

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 WEIGHS WHERE NECESSARY.
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.

FIGURE 11.7
TYPICAL PULLBOX DETAILS
FIGURE 11.8
LOW TENSION
MARSHALLING
CABINET DETAIL

NOTES:
1. THIS IS A GENERAL ARRANGEMENT FOR A TYPICAL MARSHALLING CABINET. THE ARRANGEMENT AND SIZE CAN VARY FOR EACH LOCATION.
2. FIBER TO BE DISTRIBUTED TO FIELD DEVICES EACH DEVICE TO BE EQUIPPED WITH MEDIA CONVERTER IN THE FIELD.

SPECIFICATION FOR CABINET:
- EMI ISOLATED ENCLOSURE
- STEEL WELDED CONSTRUCTION
- SPECIFICALLY DESIGNED AS WATER TIGHT, THREE DOORS PER SIDE
- 2 POINT STAINLESS STEEL, PADLOCKABLE HANDLE, HIDDEN HINGE AND 1.25 mm LOW SIDE LOCK PER SIDE
- 5.5 mm FRONT OVERHANGING BRACKETS, CROSS BURNE ROOF, SELF MACHINE FORGED CORNERS AND LIFTING LUGS
- DRAWER BACKWALLS
- NO CENTER HANGER
- INTERIOR RELATION PACKAGE

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ELECTRICAL SYSTEMS

Date Revision
NOTES:

1. THIS IS A GENERAL ARRANGEMENT FOR A TYPICAL MARSHALLING CABINET. THE ARRANGEMENT AND SIZE CAN VARY FOR EACH LOCATION.

SPECIFICATION FOR CABINET:

- ENCLOSED ENCLOSURE
- STEEL WELDED CONSTRUCTION
- SPECIFICALLY DESIGNED AS RAIN TIGHT; THREE DOORS PER SIDE
- 3 MORT STAINLESS STEEL, FORGETABLE HANDLE, HIDDEN HINGE AND 123 mm LOW NOOK KEY PER SIDE
- 3.5 mm FRONT METAL THICKNESS, CROWNED ROOF, SOFT MACHINE FORMED CORNERS AND LINING ENDS
- GALVANIZED RADIATORS
- MID-GRADE HANDED
- INTENDED ILLUSION (PAINTED)

FIGURE 11.9

POWER MARSHALLING CABINET DETAIL
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FIGURE 11.10
TYPICAL CATHEDRAL POLE GROUNDING DETAILS
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<td>12.12</td>
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<td>12.6</td>
<td>Valve Schedule</td>
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<td>12.7</td>
<td>Design Indoor Temperature and Relative Humidity</td>
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<td>12.8</td>
<td>Mechanical Ductwork Identification</td>
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<tr>
<td>12.9</td>
<td>Duct Equipment Identification Labels</td>
<td>12.21</td>
</tr>
<tr>
<td>12.10</td>
<td>Duct Insulation Schedule</td>
<td>12.21</td>
</tr>
</tbody>
</table>
12.0 MECHANICAL

12.1 INTRODUCTION

This chapter provides 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 LRT infrastructure are to 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 NPC. Each branch and main of any hydronic (heating and cooling) system must be labelled with the design flowrate, 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 outlines the level of detail to be provided in 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 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 submitted as a single binder.

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 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 possible, 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.

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 0.37 kW. All motors equal to or less than 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 0.37 kW. All motors greater than 0.37 kW are to 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
The mechanical system Design must include information on the supply and installation of VFD for building mechanical systems. 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 possible. 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
Provision of concrete housekeeping pads for equipment is 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.

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 and vandalism. Bollards should be used to protect gas meters near roadways.

12.3.2 Storm Sewers
Storm services for Stations and Ancillary Facilities must be gravity flow where practicable.
Stormwater lift stations may be considered where gravity service is not feasible 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 will only be considered if pipe installation below frost depth is not possible.

**12.3.3 Sanitary Sewers**
Sanitary services for Stations and Ancillary Facilities must be by gravity where practicable.

Sanitary lift stations may be used when gravity service is not feasible. 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 will only be considered if pipe installation below frost depth is not possible.

**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 and 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. A dedicated fire protection water supply will generally not be available.

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 will only be considered if pipe installation below frost depth is not possible.

**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 (TP) 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 backflow prevention device must be located outside the space inside a valve box with full access.

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 will only be considered if pipe installation below frost depth is not possible.

### 12.4.2 Piping 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 [12].

#### Table 12.1 Piping Colours

<table>
<thead>
<tr>
<th>Primary Colours for Piping</th>
<th>Primary Colours for Piping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>17038</td>
</tr>
<tr>
<td>Yellow</td>
<td>13591</td>
</tr>
<tr>
<td>Green</td>
<td>14193</td>
</tr>
<tr>
<td>Orange</td>
<td>12473</td>
</tr>
<tr>
<td>Brown</td>
<td>10115</td>
</tr>
<tr>
<td>Red</td>
<td>11350</td>
</tr>
<tr>
<td>White</td>
<td>17860</td>
</tr>
<tr>
<td>Aluminum</td>
<td>16515</td>
</tr>
<tr>
<td>Blue</td>
<td>15180</td>
</tr>
<tr>
<td>Grey</td>
<td>16293</td>
</tr>
<tr>
<td>Light Blue</td>
<td>15450</td>
</tr>
<tr>
<td>Purple</td>
<td>17155</td>
</tr>
</tbody>
</table>

#### Table 12.2 Application of Colour Codes to Type of Piping

<table>
<thead>
<tr>
<th>Service</th>
<th>Background</th>
<th>Lettering</th>
<th>WHMIS Symbol</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinkler</td>
<td>Red</td>
<td>White</td>
<td>N/A</td>
<td>WET SPRINKLER</td>
</tr>
<tr>
<td>Wet Standpipe</td>
<td>Red</td>
<td>White</td>
<td>N/A</td>
<td>WET STANDPIPE</td>
</tr>
<tr>
<td>Dry Standpipe</td>
<td>Red</td>
<td>White</td>
<td>N/A</td>
<td>DRY STANDPIPE</td>
</tr>
<tr>
<td>Clean Agent (Fire)</td>
<td>Red</td>
<td>White</td>
<td>Yes</td>
<td>CLEAN AGENT</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Yellow</td>
<td>Black</td>
<td>Yes</td>
<td>[ ]kPa NATURAL GAS</td>
</tr>
<tr>
<td>Fluid Type</td>
<td>Color</td>
<td>Paint Color</td>
<td>Marked</td>
<td>Symbol</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------</td>
<td>-------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Vacuum</td>
<td>Aluminum</td>
<td>Green</td>
<td>Yes</td>
<td>VAC.</td>
</tr>
<tr>
<td>Compressed Air</td>
<td>White</td>
<td>Green</td>
<td>Yes</td>
<td>[ ] kPa COMPRESSED AIR</td>
</tr>
<tr>
<td>Domestic Cold Water</td>
<td>Light Blue</td>
<td>White</td>
<td>N/A</td>
<td>DOMESTIC COLD WATER</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>Light Blue</td>
<td>White</td>
<td>N/A</td>
<td>DOMESTIC HOT WATER</td>
</tr>
<tr>
<td>Domestic Hot Water Recirculation</td>
<td>Light Blue</td>
<td>White</td>
<td>N/A</td>
<td>DOMESTIC HOT WATER RECIRC.</td>
</tr>
<tr>
<td>Heating Hot Water Supply</td>
<td>Yellow</td>
<td>Black</td>
<td>N/A</td>
<td>[ ] °C HOT WATER HEATING SUPPLY</td>
</tr>
<tr>
<td>Heating Hot Water Return</td>
<td>Yellow</td>
<td>Black</td>
<td>N/A</td>
<td>[ ] °C HOT WATER HEATING RETURN</td>
</tr>
<tr>
<td>Heating Glycol Supply</td>
<td>Yellow</td>
<td>Black</td>
<td>Yes</td>
<td>[ ] °C HEATING GLYCOL SUPPLY</td>
</tr>
<tr>
<td>Heating Glycol Return</td>
<td>Yellow</td>
<td>Black</td>
<td>Yes</td>
<td>[ ] °C HEATING GLYCOL RETURN</td>
</tr>
<tr>
<td>Chilled Glycol Supply</td>
<td>Green</td>
<td>White</td>
<td>N/A</td>
<td>CHILLED GLYCOL SUPPLY</td>
</tr>
<tr>
<td>Chilled Glycol Return</td>
<td>Green</td>
<td>White</td>
<td>N/A</td>
<td>CHILLED GLYCOL RETURN</td>
</tr>
<tr>
<td>Chilled Water Supply</td>
<td>Green</td>
<td>White</td>
<td>N/A</td>
<td>CHILLED WATER SUPPLY</td>
</tr>
<tr>
<td>Chilled Water Return</td>
<td>Green</td>
<td>White</td>
<td>N/A</td>
<td>CHILLED WATER RETURN</td>
</tr>
<tr>
<td>Condenser Water Supply</td>
<td>Green</td>
<td>White</td>
<td>N/A</td>
<td>CONDENSER WATER SUPPLY</td>
</tr>
<tr>
<td>Condenser Water Return</td>
<td>Green</td>
<td>White</td>
<td>N/A</td>
<td>CONDENSER WATER RETURN</td>
</tr>
<tr>
<td>Low Pressure Steam</td>
<td>Yellow</td>
<td>Black</td>
<td>Yes</td>
<td>[ ] kPa LP STEAM</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>Brown</td>
<td>Black</td>
<td>Yes</td>
<td>FUEL OIL</td>
</tr>
<tr>
<td>Refrigerant-Liquid</td>
<td>Grey</td>
<td>White</td>
<td>Yes</td>
<td>REFRIGERANT-LIQUID</td>
</tr>
<tr>
<td>Refrigerant-Gas</td>
<td>Grey</td>
<td>White</td>
<td>Yes</td>
<td>REFRIGERANT- GAS</td>
</tr>
<tr>
<td>Lubricating Oil</td>
<td>Brown</td>
<td>White</td>
<td>Yes</td>
<td>LUBE OIL</td>
</tr>
<tr>
<td>Engine Exhaust</td>
<td>Aluminum</td>
<td>Black</td>
<td>Yes</td>
<td>ENGINE EXHAUST</td>
</tr>
<tr>
<td>Boiler Feed Water</td>
<td>Yellow</td>
<td>Black</td>
<td>N/A</td>
<td>HOT BOILER FEED WATER</td>
</tr>
<tr>
<td>Softened Water</td>
<td>Blue</td>
<td>White</td>
<td>N/A</td>
<td>SOFT WATER</td>
</tr>
<tr>
<td>Chemical Feed Line</td>
<td>Green</td>
<td>Black</td>
<td>Yes</td>
<td>CHEMICAL FEED [CHEMICAL SYMBOL (S03) (P04)]</td>
</tr>
<tr>
<td>Drains</td>
<td>Aluminum</td>
<td>Green</td>
<td>N/A</td>
<td>DRAIN</td>
</tr>
<tr>
<td>Propane</td>
<td>Orange</td>
<td>Black</td>
<td>Yes</td>
<td>[ ] kPa PROPANE</td>
</tr>
</tbody>
</table>
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 roof drainage system must be based on 1:100 year storm which is greater than the 15 mm in the Alberta Building Code (ABC) [1]. See 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 main where possible. 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 where possible. If a gravity feed system is not possible, 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 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 where possible. If a gravity feed system is not possible, 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 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 cold and hot 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.

For seasonal systems, provision for draining and blow down for winterization must be made.

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 possible, 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, self-power-generation type faucet (water wheel) must be used.

12.4.7.2 **Operator Washrooms**
Lavatories must be Barrier-Free, oval, vitreous china, self-rimming/drop-in with overflow drain, and an infrared sensor operated faucet with 1.9 litre per 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, 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 fitting is provided in Table 12.3 below.
Table 12.3 Piping Material Schedule

<table>
<thead>
<tr>
<th>System</th>
<th>Pipe</th>
<th>Fitting</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydronic heating and cooling up to 120°C and 1035 kPa</td>
<td>Black steel Schedule 40, 50 mm or less</td>
<td>Threaded</td>
<td>Screwed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Welding</td>
<td>Welded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical Grooved</td>
<td>Clamped</td>
</tr>
<tr>
<td></td>
<td>Black steel, Schedule 40, greater than 50 mm</td>
<td>Welding</td>
<td>Welded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical</td>
<td>Clamped</td>
</tr>
<tr>
<td></td>
<td>Copper water tube type L, Drawn temper</td>
<td>Wrought copper</td>
<td>Soldered, 95-5 tin-antimony</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cast copper</td>
<td>Soldered, 95-5 tin-antimony</td>
</tr>
<tr>
<td>Equipment drains and overflows</td>
<td>Galvanized steel, Schedule 40, ASTM A53-96 only</td>
<td>Galvanized</td>
<td>Screwed</td>
</tr>
<tr>
<td></td>
<td>Copper water tube, Type L, drawn temper</td>
<td>Wrought copper tin-antimony</td>
<td>Soldered, 95-5</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>ACR copper</td>
<td>Wrought copper</td>
<td>Brazed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cast copper</td>
<td>Brazed</td>
</tr>
<tr>
<td>Domestic water above grade</td>
<td>Copper water tube type L, drawn temper</td>
<td>Wrought copper</td>
<td>Soldered, 95-5 tin-antimony</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cast copper</td>
<td>Soldered, 95-5 tin-antimony</td>
</tr>
<tr>
<td>DWV above grade and buried</td>
<td>DWV copper (above grade only)</td>
<td>Cast bronze</td>
<td>Soldered, 50-50 tin-lead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrought copper</td>
<td>Soldered, 50-50 tin-lead</td>
</tr>
<tr>
<td></td>
<td>ABS</td>
<td>ABS</td>
<td>Solvent welded</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>PVC</td>
<td>Solvent welded</td>
</tr>
<tr>
<td>Storm sewer, above grade</td>
<td>DWV copper</td>
<td>Cast bronze</td>
<td>Solder, 50-50 tin-lead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrought copper</td>
<td>Solder, 50-50 tin-lead</td>
</tr>
<tr>
<td></td>
<td>ABS</td>
<td>ABS</td>
<td>Solvent welded</td>
</tr>
<tr>
<td></td>
<td>PVC</td>
<td>PVC</td>
<td>Welded</td>
</tr>
<tr>
<td>Natural gas low pressure less than 1400 kPa, inside building</td>
<td>Black steel, Schedule 40 50 mm or less</td>
<td>Threaded</td>
<td>Screwed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Welding</td>
<td>Welded</td>
</tr>
<tr>
<td></td>
<td>Black steel, Schedule 40 greater than 50 mm</td>
<td>Welding</td>
<td>Welded</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Service Type</th>
<th>Insulation Type</th>
<th>Insulation Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOT WATER HEATING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 and smaller</td>
<td>Hot pipe</td>
<td>25</td>
</tr>
<tr>
<td>65 and larger</td>
<td>Hot pipe</td>
<td>40</td>
</tr>
<tr>
<td>DOMESTIC HOT WATER AND RECIRCULATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 and smaller</td>
<td>Hot pipe</td>
<td>12</td>
</tr>
<tr>
<td>50 and larger</td>
<td>Hot pipe</td>
<td>25</td>
</tr>
<tr>
<td>REFRIGERANT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 and smaller</td>
<td>Cold pipe</td>
<td>25</td>
</tr>
<tr>
<td>30 and larger</td>
<td>Cold pipe</td>
<td>40</td>
</tr>
<tr>
<td>DOMESTIC COLD WATER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All sizes</td>
<td>Cold pipe</td>
<td>12</td>
</tr>
<tr>
<td>PLUMBING VENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All sizes</td>
<td>Cold pipe</td>
<td>25</td>
</tr>
<tr>
<td>STORM SEWER PIPING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All sizes</td>
<td>Cold pipe</td>
<td>12</td>
</tr>
<tr>
<td>Final 2 m section</td>
<td>Cold pipe</td>
<td>25</td>
</tr>
<tr>
<td>HEAT EXCHANGERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot equipment</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>HOT WATER STORAGE TANKS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot equipment</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>WATER SOFTENERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold equipment</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>ROOF DRAINS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold equipment</td>
<td></td>
<td>25</td>
</tr>
</tbody>
</table>

12.4.8.4 Mechanical Equipment Identification
Mechanical equipment must be painted as described in Table 12.5.

<table>
<thead>
<tr>
<th>Mechanical Equipment Painting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Exchangers (hot)</td>
<td>Yellow</td>
</tr>
<tr>
<td>Heat Exchangers (cold)</td>
<td>Green</td>
</tr>
<tr>
<td>Hot Water Storage Tanks</td>
<td>Yellow</td>
</tr>
<tr>
<td>Cold Water Storage Tanks</td>
<td>Blue</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Valve Type</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globe and Angle Valves</td>
<td>Throttling, drain, and vents</td>
</tr>
<tr>
<td>Ball valves (&lt;=100 mm)</td>
<td>Isolation, drain, and vents</td>
</tr>
<tr>
<td>Operator’s preference is to use ball valves instead of butterfly valves for isolation on all sizes of hydronic systems</td>
<td></td>
</tr>
<tr>
<td>Butterfly valves</td>
<td>Isolation (&gt; 100 mm)</td>
</tr>
<tr>
<td>Radiation valves</td>
<td>Throttling</td>
</tr>
<tr>
<td>Automatic Pressure Independent Balancing Valve</td>
<td>Circuit Balancing Valves</td>
</tr>
<tr>
<td>Plug valves</td>
<td>Gas</td>
</tr>
</tbody>
</table>

### 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 can be instantaneous, semi-instantaneous, or heaters with storage tanks to suit the application.

Hot water is to be supplied by standard commercial grade domestic hot water heaters. The heaters are to 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 is to 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 [3].

### 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 are to be provided with pressure taps and gauges.

All circulation pumps with motors larger than 20 hp must be base mounted units, while circulation pumps with motors 20 hp 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.

No piping, conduits, drains or any other obstructions may be mounted above the pumps that would impede their easy 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 [4].
12.5 VACUUM SYSTEM

A central vacuum system, either a permanent vacuum unit and piping or piping with provision to connect to a portable vacuum unit, must be provided in all Stations. The system must include wet/dry vacuum piping. A complete system (vacuum and piping) must be provided for Multi-Modal Stations and wet/dry vacuum piping for connection to a portable unit may 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
The vacuum system piping should be specialty rated for the application. Rigid galvanized steel piping (2-1/8"OD 11ga.) is preferred. Outlets must be located at 20 m intervals under both sides the Platform and 350 mm back from the Platform edge.

The Designer should consider providing an 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 the 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. Accordingly, 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 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 design parameters for Edmonton are provided are provided in the ABC [1]. Winter temperatures are -40°C and summer temperatures are 30°C dry bulb and 19°C wet bulb.

Indoor design temperature and relative humidity parameters are provided in Table 12.7.

Table 12.7 Design Indoor Temperature and Relative Humidity

<table>
<thead>
<tr>
<th>Room or Area</th>
<th>Indoor Design Temperature Range</th>
<th>Indoor Design Temperature (Space Set Point)</th>
<th>Indoor Relative Humidity at mid-range of Design Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRACTION POWER</td>
<td>18°C to 25°C</td>
<td>20°C during heating season and 23°C during cooling season</td>
<td>N/A</td>
</tr>
<tr>
<td>COMMUNICATION SIGNAL, TELEPHONE, RADIO EQUIPMENT</td>
<td>18°C to 24°C</td>
<td>20°C during heating season and 22°C during cooling season</td>
<td>40% to 50% (to be confirmed by the Engineer)</td>
</tr>
<tr>
<td>DATA CENTRE</td>
<td>18°C to 23°C</td>
<td>20°C during heating season and 21°C during cooling season</td>
<td>40% to 50%</td>
</tr>
<tr>
<td>ELECTRICAL ROOM</td>
<td>18°C to 28°C</td>
<td>18°C during heating season and 25°C during cooling season</td>
<td>N/A</td>
</tr>
<tr>
<td>WASHROOMS</td>
<td>20°C to 27°C</td>
<td>22°C during heating season and 25°C during cooling season</td>
<td>N/A</td>
</tr>
<tr>
<td>UTILITY/JANITORIAL STORAGE/VACUUM ROOM</td>
<td>18°C to 27°C</td>
<td>20°C during heating season and 24°C during cooling season</td>
<td>N/A</td>
</tr>
<tr>
<td>OFFICE AREA/STAFF ROOM/SECURITY ROOM</td>
<td>18°C to 25°C</td>
<td>21°C during heating season and 23°C during cooling season</td>
<td>20% to 30% during winter</td>
</tr>
<tr>
<td>ELEVATOR MACHINE ROOM/HOISTWAY</td>
<td>Refer to the requirement of the elevator machinery and equipment and AEDARSA Regulations</td>
<td>Refer to the requirement of the elevator machinery and equipment and AEDARSA Regulations</td>
<td>Refer to the requirement of the elevator machinery and equipment and AEDARSA Regulations</td>
</tr>
</tbody>
</table>
12.6.2 Heating, Cooling, and Ventilation

12.6.2.1 Traction Power Rooms
TP 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.

TP 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.

HVAC equipment should be placed outside the room where possible to avoid the need to enter the space to service, maintain, and replace equipment.

12.6.2.2 Communications and Signals 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 Signals 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 possible to avoid the need to enter the space to service, maintain, and replace equipment.

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.

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 possible to avoid the need to enter the space to service, maintain, and replace equipment.

**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 outlined 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 outlined 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 [6].

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 possible 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 outlined in this chapter, and any other criteria identified by the Engineer.

The Design must include exhaust and ventilation as per ASHRAE 62.1 [6].

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 outlined in this chapter, and any other criteria identified by the Engineer.

The Design must include exhaust and ventilation as per ASHRAE 62.1 [6].

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 review 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.

The Design must include ventilation to reduce overheating 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 outlined in this chapter, and any other criteria identified by the Engineer.

Ventilation providing a minimum of 1 ACH for a crawlspace must be included in the Design. Heating of crawlspaces is based on the utilities and equipment in the crawlspace.

If equipment is placed inside a crawlspace, the crawlspace must be sized to 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 outlined 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.

Generator rooms in residential areas require a detailed review for noise control. Muffler systems must be able to meet the noise levels restrictions required by the surrounding private property.

Vibration isolators on muffler piping and spring isolators on the hangers for exhaust pipes must be provided to accommodate 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 new facilities will not be provided with 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 outlined 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 meeting requirements of energy efficiency, redundancy, ability for future expansion, durability, ease of operation, and availability of spare parts.

All heating equipment must have the ability 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 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 meeting requirements of energy efficiency, redundancy, ability for future expansion, durability, ease of operation, and availability of spare parts.

All cooling equipment must be multi-staged or have the ability 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 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 EC motors are not available, the Design should provide VFDs for balancing and speed adjustment.

A lift rail inside air handling units must be provided if the fan motor is larger than 10 hp.

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 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 handling 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 redundancy.

12.6.4 Heating, Ventilation, and Air Conditioning Materials

12.6.4.1 Ductwork insulation
All intake, supply, 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

<table>
<thead>
<tr>
<th>Service</th>
<th>Background</th>
<th>Colour</th>
<th>Lettering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Air</td>
<td>Blue</td>
<td>White</td>
<td>RETURN AIR</td>
</tr>
<tr>
<td>Supply Air</td>
<td>Blue</td>
<td>White</td>
<td>SUPPLY AIR</td>
</tr>
<tr>
<td>Mixed Air</td>
<td>Blue</td>
<td>White</td>
<td>MIXED AIR</td>
</tr>
<tr>
<td>Combustion Air</td>
<td>Blue</td>
<td>White</td>
<td>COMBUSTION AIR</td>
</tr>
<tr>
<td>Relief Air</td>
<td>Blue</td>
<td>White</td>
<td>RELIEF AIR</td>
</tr>
<tr>
<td>General Exhaust Air</td>
<td>Blue</td>
<td>White</td>
<td>GENERAL EXHAUST AIR</td>
</tr>
<tr>
<td>Toilet Exhaust</td>
<td>Blue</td>
<td>White</td>
<td>TOILET EXHAUST AIR</td>
</tr>
</tbody>
</table>
### Table 12.9 Duct Equipment Identification Labels

<table>
<thead>
<tr>
<th>Service</th>
<th>Background</th>
<th>Lettering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning and service access</td>
<td>Yellow</td>
<td>Black</td>
</tr>
<tr>
<td>Controls, including heat sensors</td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>Dampers (backdraft, balance and control)</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Fire dampers</td>
<td>Red</td>
<td>White</td>
</tr>
<tr>
<td>Smoke dampers and detectors</td>
<td>Red</td>
<td>White</td>
</tr>
</tbody>
</table>

### Table 12.10 Duct Insulation Schedule

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Insulation Type</th>
<th>Insulation Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust and relief ducts within 3 m of exterior openings</td>
<td>Hot duct</td>
<td>25</td>
</tr>
<tr>
<td>Relief ducts and plenums</td>
<td>Hot duct</td>
<td>25</td>
</tr>
<tr>
<td>Supply ducts and plenums</td>
<td>Hot duct</td>
<td>25</td>
</tr>
<tr>
<td>Combustion air</td>
<td>Cold duct</td>
<td>50</td>
</tr>
<tr>
<td>Outside air</td>
<td>Cold duct</td>
<td>50</td>
</tr>
<tr>
<td>Mixing plenums</td>
<td>Cold duct</td>
<td>50</td>
</tr>
<tr>
<td>Supply air plenums</td>
<td>Cold duct</td>
<td>25</td>
</tr>
<tr>
<td>Supply ducts</td>
<td>Cold duct</td>
<td>25</td>
</tr>
<tr>
<td>Supply and return ducts exposed to outdoors</td>
<td>Cold duct</td>
<td>50</td>
</tr>
<tr>
<td>Supply and return ducts in cold attic spaces</td>
<td>Cold duct</td>
<td>50</td>
</tr>
<tr>
<td>Supply and return</td>
<td>Acoustic</td>
<td>25</td>
</tr>
<tr>
<td>Supply and return Exposed to Outdoors</td>
<td>Acoustic</td>
<td>50</td>
</tr>
<tr>
<td>Plenums</td>
<td>Acoustic</td>
<td>25</td>
</tr>
<tr>
<td>Boilers</td>
<td>Breeching</td>
<td>50</td>
</tr>
<tr>
<td>Domestic hot water heaters, atmospheric burners</td>
<td>Breeching</td>
<td>25</td>
</tr>
<tr>
<td>Furnaces</td>
<td>Breeching</td>
<td>25</td>
</tr>
<tr>
<td>Gas-fired unit heaters</td>
<td>Breeching</td>
<td>25</td>
</tr>
<tr>
<td>Indirect gas-fired air handling units, forced air burners</td>
<td>Breeching</td>
<td>25</td>
</tr>
<tr>
<td>Indirect gas-fired air handling units, atmospheric burners</td>
<td>Breeching</td>
<td>50</td>
</tr>
</tbody>
</table>

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 are to 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 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 report prepared by an acoustical consultant.

**12.6.4.2 Dampers and Louvres**

All dampers must to be provided with end switches that signal back to the BMS for confirmation of opening and closing. All dampers to the outside must be ultra-low leakage, insulated type and extreme cold weather seals. All louvres must be drainable, allowing the largest effective area. All louvres must be 150 mm in depth and sized to be 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 by a specific application. The use of stainless steel and other special type of ducting material may be required for specific applications.

Medium or high pressure and velocity ductwork must only be used when required for a specific application. The use of medium or high velocity ductwork 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. See 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 is equipment that is necessary for monitoring and controlling HVAC equipment at Platforms, Stations, Utility Complexes, and any other LRT facilities.

The LRT switch blower control, 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 maintenance facilities, underground tunnels and pedways on the LRT System are provided with building HVAC and plumbing systems which are all controlled and/or monitored by the BMS. Dedicated controllers within each facility or building are connected back to the LRT Operations Control Centre (OCC).

**12.8.1 Existing Building Management System Infrastructure**

The existing LRT BMS is a proprietary system supplied by Delta Controls and installed by ESC Automation of Edmonton.

ESC Automation must be contacted to confirm existing control system firmware and hardware and to coordinate compatibility requirements between the existing and new BMS equipment.
The Designer must contact the Engineer or ESC Automation for the most current version of hardware and software currently being used at the various facilities.

12.8.1.1 Main Network
The main network consists of a dedicated VLAN that spans the entire LRT LAN network into all facilities that require BMS. This network is a dedicated network on the same Cisco infrastructure that runs all other communications systems. The network is firewalled from other ETS systems by the central core firewall and the only access allowed in from external networks is via a VPN portal and to the http ports of the main Delta web servers.

This system will likely be migrated to a Virtual Private LAN Service (VPLS) on the new Multi-Protocol Label Switching (MPLS) core network as part of the common infrastructure environment network build. The same topology for the network will continue to exist as today.

Network switches are provided at each facility to allow for the interconnection of the individual Facility Network into the main network. These switches are part of the shared core network that runs all communications systems.

12.8.1.2 Facility Network
Each Station, Utility Complex and the D.L. MacDonald (DLM) LRT Maintenance Facility has its own access layer switches that branch out to all locations that contain BMS controllers.

The networks within each facility, consists mainly of copper network cabling, except where conventional copper network cabling (Cat 6) distances are exceeded. Where copper network cabling distances are exceeded, fibre optic network cabling is used. Industrially hardened ethernet switches with optical fibre Small Form-Factor Pluggable (SFP) transceivers must be used to gather copper based signals for transmission over fibre to the main station network switch.

Signal amplifying devices must not to be used to overcome cabling distance limitations of copper type network cable. Individual fibre media converters should not be used unless approved by the Operator. All copper runs must also conform to BICSI/TIA standards for installation as with any Cat 6 installation described in this document.

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 as outlined 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
The new BMS equipment provided for any new facility will 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 be fully integrated into the existing BMS system.

12.8.2.3 Interfacing Requirements
The BMS interfaces 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, in Appendix 12-A, identifies the major LRT functions, by element, that are controlled centrally. It 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. This must be coordinated with the Operator.

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 will have dedicated ports provisioned for the BMS panels at each location.

12.8.3.3 Main Control Panels
Fully distributed BMS control panels must be provided in communication, mechanical, electrical, Signals and other rooms 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 Delta control system. Upgrading of all software and firmware for existing BMS Controllers may be required in order to interface the new Controllers to existing Controllers. Where possible, upgrading should include all existing Controllers with the overall objective of maintaining the newest software and firmware versions throughout the system.

New Controllers must be fully capable of operating in standalone 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 standalone 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 not connect directly to the Facility Network or the main network. They must be networked directly to a main control panel via a sub-network dedicated to one specific main control unit. LCP must be fully programmable controllers.

All control panels must be enclosed within metal enclosures complete with lockable door latches.

The primary power supply for all LCPs must be provided via the facility power system. Central emergency power must be used, if provided in the facility, as the primary power supply for all LCPs. Individual or central UPS, for the secondary power system to the LCP, must be provided.

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, is acceptable.

12.8.3.6 Local, Facility, and Remote Operator Workstations
Access to the BMS is through a webpage 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, the Operator will provide a list of acceptable sensors and device type products.

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. Existing graphic formats previously used in existing facilities are to be used 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 is to 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 will 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 are also to be logged at the BMS servers.

Individual alarm conditions are to be specified for the various system points in order to alert the Operator’s personnel to alarm conditions normally expected from BMS systems being monitored and controlled. Where possible, 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 outlines 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.

Appropriate number of control points should be provided to ensure fully operational HVAC systems and equipment meeting the intended sequence of operation.

Appropriate number of monitoring points should be provided to allow full diagnostic of HVAC systems and equipment for performance and alarms. Ability of remote troubleshooting of Operation and Maintenance (O&M) must be incorporated into the control and monitor points list.

Refer to the Operator’s BCP for control and monitoring points 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 of Domestic Hot Water Tank Heater on trip 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 System Monitoring (UPS)
- Automatic Transfer Switch Monitoring (ATS)
- 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

12.8.6 Training
Training must be provided to the Operator’s staff for all new facilities and their related systems, including the expansion of the existing system. BMS training will be 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.

Documentation must include loop drawings.

12.9 FIRE PROTECTION SYSTEMS

The Design must provide a fire protection system to meet the requirements of ABC, Alberta Fire Code (AFC) [7], 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.

The main fire protection equipment 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 is to be installed in locations where required by code. Standpipe systems must be designed to NFPA 14 [8] with hose connections meeting the standards set out in NFPA 1963 [9]. The fire hose system is split into two systems dependent on the size of the facility and the location within the LRT facility. It 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 must be included on all Platforms. 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 are to be located no more than 1200 mm above Top of Rail (TOR) and are to 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. Should a break occur in the main line, that section of line could be valved off with the remaining hose stations being useable.

Each hose station must be equipped with two 15m lengths of service attack hose. Each hose length has a diameter of 44 mm complete with 38 mm couplings. The hose must be double jacketed.

The hose nozzle is to be FRS standard fog and straight steam nozzle. The nozzle is constructed to have double row of molded rubber-like teeth as an integral of the bumper.

12.9.2.2 **Fire Department Connections**
The Design must include fire department connections in accordance with ABC [1], AFC [7], and building code references to NFPA standards. The Designer must coordinate locations with FRS.

Fire department connection locations must have a lamacoid nameplate indicating the area being served and the fire department 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 fire department 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 are a standard requirement.

Valve locations must be reviewed by and coordinated with FRS.

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.
Spinkler 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 [10].

The clean agent must meet the following requirements:

- Zero ozone depletion potential
- Global warming potential less than one
- 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 [1], AFC [7], and NFPA 10 [11].

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, adjacent to flammable liquids storage and handling.

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 two major types of ventilation systems that 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 Stations ventilation system provides an acceptable level of environmental quality for Patrons and service personnel carrying out their responsibilities in these areas. 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 on an individual basis.
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)s moving through the tunnels provides the ventilation under normal conditions. Blockage ratio, impedance, and the speed of the Train is 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 the existing ventilation system must be compatible and totally integrated to the existing system.

Fans designated for the control and direction of air flow are required to 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 ensure fans are at 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 are to 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.
## APPENDIX 12A

BMS Systems Interface Matrix

### BMS Points

<table>
<thead>
<tr>
<th>Function/Element</th>
<th>Subsystem</th>
<th>Analog</th>
<th>Digital</th>
<th>Control &amp; Monitor</th>
<th>Monitor Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stations</td>
<td>Interior/exterior lighting</td>
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### BMS Systems Interface

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<tr>
<th>Item</th>
<th>Function/Element</th>
<th>Subsystem</th>
<th>Analog</th>
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Corrosion and Stray Current
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13.0 CORROSION AND STRAY CURRENT

13.1 INTRODUCTION

This chapter presents guidelines related to soil corrosion and Stray Current control measures which are required to minimize Stray Current leakage and prevent premature corrosion failures of 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 Currents 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, LRT projects must include documentation to verify that the appropriate corrosion control measures are implemented in the Design as outlined in this chapter. The two main documentation requirements are a Stray Current Survey and a Stray Current Mitigation Plan, which are defined 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 to adjacent privately-owned facilities and conductive structures that may be caused by stray earth 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.

- Protection of Metals in Concrete Against Corrosion [6]
- Standard Practice for Determining Rail-to-Earth Resistance [8]
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 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 extensive 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.

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 completed by the Designer. The Design must minimize impacts on LRT System elements.
13.3.2 Materials and Methods

13.3.2.1 Coatings
Coatings specified for corrosion control of conductive or concrete structures must have a chemical or mechanical bond to the metal or concrete surface; pressure-sensitive systems (e.g. adhesives) are not acceptable. Non-bonding systems may be used in special instances, after review and acceptance by the Engineer.

Application of coatings is to be at the mill wherever possible, with field application of a compatible paint or tape system. 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 service (minimum 5 years) and be compatible with the base metal to which they are applied.

Finishes must have demonstrated satisfactory gloss retention, color retention, and resistance to chalking over their life expectancies.

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 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 are to be provided per joint for redundancy.

13.3.3 Utilities and Underground Conductive Structures
Protective measures to be considered for utilities and underground conductive structures are described below.

13.3.3.1 Ferrous Pressure Piping
All new buried cast iron, ductile iron, and steel pressure piping must have cathodic protection.

13.3.3.2 Copper Piping
Buried copper pipe must be electrically isolated from non-buried piping and structural elements. 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, which are not considered to 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 increased cylinder wall 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 earth traction current from LRT operations on conductive structures.

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 basic requirements for the control of Stray Current are as follows:

- Eliminate direct and indirect electrical connections between the positive and negative Traction Power (TP) distribution circuits and ground
- Minimize Stray Current during normal revenue operations through Design of the Traction Power System (TPS) as found in Chapter 6, Traction Power and Chapter 5, Trackwork

13.4.1 General Documentation Requirements

To support the Stray Current design, the Designer will develop a Stray Current Mitigation Plan and a Stray Current Survey.

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 amplitude and mitigate the effect of Stray Current
• Identify all components within and outside of the LRT ROW which are at risk from Stray Current corrosion, and the means of protection for each
• 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

The purpose of the Stray Current Survey is to establish a baseline for the prevailing Stray Current prior to construction of the LRT project. 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), including:
  - Determine through calculations or measurement, the pre-existing Stray Current, grounding characteristics, and (if applicable) touch potentials for sensitive interfaces, such as:
    • Traction Power Substation (TPSS)
    • Positive and negative distribution system, including rail-to-earth resistance
    • Cross Bonds and track insulation
    • Stray Current leakage path controls
    • Earthing systems
    • At-Grade and elevated guideways
    • Maintenance facilities
    • Adjacent conductive structures
    • Utilities and pipelines
  - Determine through calculation or measurement, the pre-existing leakage current characteristics that have the potential to interfere with sensitive Train equipment.
  - Establish the post-project Stray Current baseline, inclusive of implemented Stray Current mitigations, for the project area(s).
• Complete post-project Stray Current calculations and measurements to determine the effect of the project on Stray Current
• 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.

13.4.2.2 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 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.

13.4.2.3 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 (where practicable)
- 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

13.4.2.4 Level crossings
The conductance per unit length between Direct Current (DC) negative circuit and ground at level crossings must not exceed the value of the neighbouring tracks when running rails are in embedded track.

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).

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
The positive distribution system must be designed as an electrically continuous bus network. Intentional electrical segregation of Mainline, Yard, and Shop positive distribution systems is the only type of segregation permitted.

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 should ensure that electrical continuity is established between support poles and foundation reinforcing steel to dissipate Stray Current generated by the positive distribution system. The Design must size the cables connecting the OCS support pole and steel foundation based on the calculated fault current and clearing time. Where practical, the steel foundation for a support pole must be grounded.
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 track-to-earth conductance and must ensure insulation quality of the rails toward ground will not be diminished substantially by water. Refer to Chapter 16, Utilities and Drainage for drainage requirements.

All dead-ended tracks must have isolation joints installed to isolate bumping posts and other similar devices that are electrically grounded.

For ballasted track, clean, high resistivity ballast material with adequate drainage and appropriately designed insulating track fastening devices, such as insulated tie plates, direct fixation fasteners or other methods accepted by the Engineer must be provided. The top of the ballast material should be minimum of 25 mm below the bottom of all metallic surfaces.

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.

13.4.3.4 Isolation from Conductive Structures
Electrical connection between conductive structures and the Return Circuit must be avoided to prevent the risk of Stray Current exchange corrosion. If a connection to the Return Circuit exists, rail to structure ground connections must be removed promptly and continuous monitoring must be provided.

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.

An open connection between equipment and the Return Circuit must be provided, including a Voltage-Limiting Device (VLD) if required.

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 (OMFs)
Yard Track must be electrically insulated from Mainline track and from ground. Within the 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

Conductive LRT structures, including tunnels, bridges, and reinforced concrete slabs are susceptible to the effects of Stray Current. Stray Current control measures depend on whether the predominant source of Stray Current is internal or external with respect to the conductive structure, and whether the priority is protection of the conductive LRT structure, or of the external conductive structures.

13.4.4.1 Section Isolation

Conductive LRT structures may be divided into longitudinal sections, with Insulating Joints to prevent Stray Current from flowing into the structure. Terminals must be provided at ring joints between each section for testing purposes.

Corrosion must not be caused at the Isolating Joint by current flow across the Insulating Joint through the ground. Adequately sized Bonds across Insulating Joints and acceptable rail to ground resistance must be provided.

13.4.4.2 Equipotential Bonding

Stray Current flowing through conductive LRT structures can affect external conductive structures. These effects can be reduced by equipotential Bonding between the structures, or by providing a separate low-resistance path for Stray Current. This can be achieved by:

- Sufficient quantity of reinforcing bars between the structures
- Conductive mats connected between the structures
- Electrical connections between other conductive structural parts
- Adding conductors of appropriate cross-section to provide a low resistance path for Stray Current

13.4.4.3 Bridges

Stray Current control on bridges must provide a ground electrode system at each end of the bridge and at intermediate locations along the bridge. The number, location, and earth resistance of the ground electrode system must be determined by and documented in the Stray Current Mitigation Plan.

When possible, the Designer must provide electrical isolation of reinforcing steel in the deck and superstructure from columns, abutments, and other grounding elements.

The Design must maintain continuity of the top layer of reinforcing steel using collector bars at expansion joints, hinges, and abutments, that are connected with a minimum of two cables. Additional collector bars at intermediate locations along the bridge should be included, and the location and spacing of the collector bars must be determined by, and documented in, the Stray Current Mitigation Plan.

The Design must provide test facilities at each end of the bridge, and at intermediate locations along the bridge. The test facilities must house test wires from collector bars and the ground electrode system (if present). The location and spacing of the test facilities must be determined by, and documented in, the Stray Current Mitigation Plan.

For bridge applications with ballasted track, the Design must include a waterproof membrane with protection board over the entire deck surface that is in contact with the ballast. In addition, the Design must include a continuous collector grid directly on top of the protection board and beneath the ballast that extends the full Trackway width.
13.4.4.4 Underground Structures
Stray Current control on underground structures must maintain continuity of the top layer of reinforcing steel using collector bars at expansion joints, hinges, and abutments, that are connected with a minimum of two cables.

The Design must include additional collector bars at intermediate locations along the underground structure. The location and spacing of the collector bars must be determined by, and documented in, the Stray Current Mitigation Plan. Test facilities at all collector bars must be included.

Underground structure cross sections should include space for a cathodic protection rectifier, distribution conduit and power supply.

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.

13.4.4.5 External Cables, Pipework, and Power Supply
On bridge structures and in underground structures, metallic pipe work, hydraulic lines, and cable sheaths must be electrically separated from 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 specified 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 feasible, 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 specified 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 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 can 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.
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.
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14.0 URBAN INTEGRATION

14.1 INTRODUCTION

This chapter provides guidelines for the integration of 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) [1]
- Alberta Fire Code (AFC) [2]

14.1.1.2 Policies and Bylaws

- City of Edmonton Community Standards Bylaw 14600 [3]
- City of Edmonton Zoning Bylaw 12800 [4]
- City Policy C602 Accessibility for People with Disabilities (supersedes C463, C466 and the ETS Accessible Transit Instruction)
- City Policy C458C Percent for Art to Provide and Encourage Art in Public Areas [6]
- City Policy C573A Complete Streets [7]
- City Policy C565 Transit Oriented Development [8]

14.1.1.3 Design Standards and Guidelines

- Complete Streets Design and Construction Standards (CSDCS) [9]
- City of Edmonton Design and Construction Standards (D&CS) [10]
- High Floor, Urban Style LRT Sustainable Urban Integration Guidelines
- Crime Prevention Through Environmental Design (CPTED) Principles [12]
- City of Edmonton Wayfinding Design Standards, 2016

14.2 LRT RIGHT-OF-WAY DELINEATION

14.2.1 Application of Transportation Corridor and Operations Matrix

The Transportation Corridor and Operations Matrix presented 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 preclude 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 [14] or concrete walls designed for vehicle impact. The addition of pedestrian exclusion fencing to the vehicle barriers may be required 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 discussed in Chapter 17, Streets.

14.2.1.2 Soft Barrier – Delineation
Soft barriers must be designed to provide visual and tactile warning to pedestrians, cyclists and motorists of the presence of the Trackway. 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 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.

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 their 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 intersection 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 signal 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 node 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 the 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 bins, 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 [12]
- 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, owing to their unique community setting or regional importance, must be scaled and appointed in a way that can accommodate other urban design objectives. 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 possible to create Stations that are more seamlessly integrated with 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 [1] and the Alberta Barrier Free Guideline [15]. 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 [13]. 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 details.

#### 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 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 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 [13], as well as the City of Edmonton Pedestrian Wayfinding Design Standards.

The Designer must consider sightlines at nodes, pathways, and plazas to allow people using active modes of transportation to clearly identify the route to Stations and its 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 platforms.

A lay-by designated for paratransit vehicles should be provided where all 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, 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 seamless integration between facilities. This will provide a coherent and high-quality Patron experience and support the 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-modal connections, and other plaza areas.

Refer to the Complete Streets Design and Construction Standards [9].

**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's High Floor Urban Style SUI Guidelines 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 [13], as well as the most
current versions of the ETS Signage Design Guidelines and City of Edmonton Pedestrian Wayfinding Design Standard [16].

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 a minimum of 2.5 m from edge of Trackway
- Coniferous trees: trunk must 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 involves significant 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 often leaves little 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 outline 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) visibility. 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 reduction in friction between 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 possible 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 LRT ROWs generally have 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 outlined 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 feasible due to maintenance or other issues. Naturalization strategies should also be considered on any slopes or drainage swales.
Planting beds and naturalization areas are generally preferred over 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 must 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) [4]. A noise study must be undertaken in support of the design for new or upgraded LRT facilities and noise mitigation will be required 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 will be required 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 [3].

**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 possible while still maintaining full functionality of the warning system.

**14.6 SIGHTLINES**

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 should 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 an almost complete 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.
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CHAPTER 15
Safety and Security
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15.0 SAFETY AND SECURITY

15.1 INTRODUCTION

This chapter presents the principles and guidelines for safety and security measures of Passengers and Patrons as well as ETS service and maintenance staff in:

- Stations
- Adjacent pedestrian and bicycle facilities
- Parking areas
- Patron drop-off areas
- LRT Right-of-Way (ROW)
- Light Rail Vehicles (LRV)
- Ancillary Facilities

Where applicable, requirements of the Alberta Building Code (ABC) [1] and the National Building Code (NBC) [2] must be applied. To ensure industry standards are being met, other reference documents such as National Fire Protection Association (NFPA) 130 [3], American Public Transportation Association (APTA) Standards Infrastructure and Systems Security [4], and the Design Guide for a Safer City [5] should be used for each Design when building codes do not address specific design elements.

15.1.1 Applicable Codes, Standards, Regulations, Design References

- Alberta Building Code (ABC) [1]
- National Building Code of Canada (NBC) [2]
- City of Edmonton Zoning Bylaw #12800 – Regulation 58 General Performance Standards for a Safe Physical Environment [7]
- City of Edmonton Design and Construction Standards [8]
- Crime Prevention Through Environmental Design (CPTED) [9]
- Design Guide for a Safer City [5]

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 [5] 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 [5] 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:
15.2.3  LRT Facility Interior and Exterior Access Routes and Areas

15.2.3.1  Sightlines
Clear visibility of the path along a given travel route is critically important. A user’s Line of Sight 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.

Sightlines should be unobstructed based on users that include pedestrians (adult or child and wheelchair height), cyclists, motor vehicle drivers 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 a barrier such as walls 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 sightlines such as stairwells
- Use mirrors to aid the TO with sightlines 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 and exits to and 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 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 telephones 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 System
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 to safety and security issues. The loudspeakers 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:
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- 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
- A battery powered emergency lighting system which will provide a minimum of 4 hours of illumination in all Traction Power Substations (TPSS) and Utility Complexes
- Avoidance of spotlighting points, which leaves surrounding areas less visible
- Lighting devices that must be 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, understandable, and consistent 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 the Platform edge 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.

Sightlines and view obstructions must be considered during landscape design to avoid the creation of blind spots or entrapments as vegetation matures. Sudden changes in grade due to landscaping should be avoided as they may impede sightlines.

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
• Conflicts 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 Station entrances
• Dead-end drive aisles must not be used
• Illumination levels must be in accordance with Chapter 11, Electrical
• All ground level motor vehicle entrances and exits must have a rolling steel door or equivalent
• 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 within Line of Sight.

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 [10].

Tunnel sections must have yellow advisory lights at each tunnel entrance with unobstructed sight lines for the TO.

Tunnel Cross-Connections are required at a minimum spacing of 500 m.

15.3.4.2 Bridge or Elevated Guideway 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 the 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 presented in Chapter 7, Signals. Safety measures at motor vehicle, cyclist, and pedestrian At-Grade crossings are outlined 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 workers. 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.

Sightlines of LRVs and maintenance vehicles should be considered when placing LRT ROW elements such as bungalows, cabinets and crossing controls.

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 [1] and NFPA 130 [10].

All tunnel sections of the LRT ROW must provide for fire-life safety systems. Each tunnel section must have a hazard assessment completed to determine if fire-life safety systems are needed.

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 detailed 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 it is for a Station, the LRT ROW, or LRV, is paramount. Assets should be designed to be easily maintained with the least 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.

Winter maintenance is a key operational requirement. Snow storage areas must be included in the Design of 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 sightlines.
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Utilities and Drainage
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16.0 UTILITIES AND 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 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 [1], 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) [2] 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 [3], as the Design storms included in this document take 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 90° 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. Casing must
be non-conductive, continuous, and extend a minimum of 6.0 m beyond the track centreline on both sides of the LRT ROW.

All utilities beneath the LRT ROW that are to be abandoned must be removed. If removal is not practicable, then they must be abandoned in place as accepted by the Engineer.

Future utility crossings may be constructed 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 locations have been defined.

Utilities must be designed and constructed to minimize the impact of Stray Current. Where possible, utilities should be constructed with non-conductive material. Refer to Chapter 13, Corrosion and Stray Current.

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 the 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. 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 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. Pressurized 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.

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 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 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 utilizes 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 1.5m 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 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 utilizes 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 [2] 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 [2] Chapter 3 Drainage, EPCOR’s Guideline for Stormwater Management, Alberta Safety Codes Act [4], and ABC [5]) 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 is required.

Backflow prevention valves 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

<table>
<thead>
<tr>
<th>Storm Infrastructure</th>
<th>Design Storm Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tie and Ballast Track (subdrains or ditches)</td>
<td>1:25-year rainfall event</td>
</tr>
<tr>
<td>Embedded Track (storm conveyance pipes)</td>
<td>1:5-year rainfall event</td>
</tr>
<tr>
<td>Direct Fixation Track (storm conveyance pipes)</td>
<td>1:5-year rainfall event</td>
</tr>
<tr>
<td>Underpass Stormwater Management</td>
<td>Larger of the 1:100-year 4-hour and 24-hour rainfall event evaluated through discussions with the Engineer</td>
</tr>
<tr>
<td>Bridge Stormwater Management</td>
<td>Larger of the 1:100-year 4-hour and 24-hour rainfall event evaluated through discussions with the Engineer</td>
</tr>
</tbody>
</table>

**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 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 [6] 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 feasible, retention ditches or ponds should be provided.

Ponding and overland flow within the Trackway must not exceed the TOR for any type of track, 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 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 ballasted track must be prevented from entering the ballasted track sections by being intercepted, controlled and redirected away from the ballasted 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 ballasted track.

Overland flow is not permitted to enter and then flow along the Trackway for any track type.

Table 16.2 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

<table>
<thead>
<tr>
<th>Track Type</th>
<th>1:5-Year Design Event Ponding Limit above Top of Rail</th>
<th>1:100-Year Design Event Ponding Limit above Top of Rail</th>
<th>Comments on Ponding/Overland Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballasted Track</td>
<td>0 mm</td>
<td>0 mm</td>
<td>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.</td>
</tr>
<tr>
<td>Embedded Track</td>
<td>0 mm</td>
<td>Lesser of 100 mm or safe LRV operation limit</td>
<td>Overland flow is permitted to cross.</td>
</tr>
<tr>
<td>Direct Fixation Track</td>
<td>0 mm</td>
<td>0 mm</td>
<td>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.</td>
</tr>
</tbody>
</table>

### 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 Ballasted Track Drainage

Drainage systems for ballasted track may consist of drainage ditches or sub-drains depending on site constraints.
A general ballasted Trackway configuration is presented in Chapter 5, Trackwork.

**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 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.

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 general embedded Trackway configuration is discussed in Chapter 5, Trackwork.

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 general direct fixation Trackway configuration is discussed in Chapter 5, Trackwork.
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 Grade Crossing Drainage Considerations**
At-Grade LRT crossings of roads and pedestrian crosswalks must as a minimum match the general approach grade and preferably 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 ballasted 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 outlined 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 [2] 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.
Ballasted 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 Operations and Maintenance Facilities (OMF) must be managed onsite 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

<table>
<thead>
<tr>
<th>Utility</th>
<th>Depth (To Top Of Utility)</th>
<th>Parallel Clearance</th>
<th>Crossing Clearance</th>
<th>Crossing Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm Sewers</td>
<td>0 – 7 m</td>
<td>• Minimum 2.0 m from edge of LRT ROW to edge of pipe.</td>
<td>• Minimum 2.0 m from top of rail to pipe obvert.</td>
<td>• Not required for gravity sewers.</td>
</tr>
<tr>
<td>Sanitary Sewers</td>
<td></td>
<td>• May be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a case by case basis.</td>
<td>• Pipe must be protected from freezing.</td>
<td>• Pressure pipes to be cased a minimum of 6.0 m beyond the track centreline.</td>
</tr>
<tr>
<td>Combined Sewers</td>
<td></td>
<td>• MHs/CBs/App urtenances must be relocated to meet minimum clearance requirements.</td>
<td>• Must meet minimum crossing clearance (above).</td>
<td>• All pipes to avoid crossing Platforms, otherwise they must be cased and avoid conflicts with the Platform foundation.</td>
</tr>
<tr>
<td>Water</td>
<td>All</td>
<td>• Minimum 2.0 m from top of rail to pipe obvert.</td>
<td>• Minimum 2.0 m from top</td>
<td>• Casing required for all pressure</td>
</tr>
<tr>
<td>Utility</td>
<td>Depth (To Top Of Utility)</td>
<td>Parallel Clearance</td>
<td>Crossing Clearance</td>
<td>Crossing Protection</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>All</td>
<td>• Existing infrastructure to be located a minimum of 1.0 m from edge of LRT ROW to centreline of pipe. &lt;br&gt; • New or relocated infrastructure to be located a minimum of 1.5 m from edge of LRT ROW to centreline of pipe. &lt;br&gt; • May be located within the Urban Interface zone if sufficient width exists upon approval of the Engineer on a case by case basis.</td>
<td>• Minimum 1.83 m from top of rail to pipe obvert. &lt;br&gt; • Pipe must be protected from freezing.</td>
<td>• 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.</td>
</tr>
</tbody>
</table>
### Utility Depth

**Utility**

<table>
<thead>
<tr>
<th>Underground Power Distribution Infrastructure</th>
<th>Depth (To Top Of Utility)</th>
<th>Parallel Clearance</th>
<th>Crossing Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Engineer on a case by case basis.</td>
<td>• Appurtenances must be relocated to meet minimum clearance requirements.</td>
<td>• Utility must be in conduit for crossing and must be non-conductive, continuous, and extend a minimum of 6.0 m beyond track centreline.</td>
</tr>
</tbody>
</table>

**Utility Depth**

- **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 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.
- • Minimum 1.83 m from top of rail to utility.
<table>
<thead>
<tr>
<th>Utility</th>
<th>Depth (To Top Of Utility)</th>
<th>Parallel Clearance</th>
<th>Crossing Clearance</th>
<th>Crossing Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground Power Transmission Infrastructure</td>
<td>All</td>
<td>• Must be evaluated for relocation through discussions with the utility provider and the Engineer on a case by case basis.</td>
<td>• Must be evaluated for relocation or protection through discussions with the utility provider and the Engineer on a case by case basis.</td>
<td>• Must be evaluated for relocation or protection through discussions with the utility provider and the Engineer on a case by case basis.</td>
</tr>
</tbody>
</table>
| 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 within the LRT ROW or Urban Interface zones. | • 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. |
| Overhead Utilities (Power Distribution, Transmission and Telecommunication Infrastructure) | N/A                        | • Minimum of 9.0 m from centreline of track to utility poles for distribution | • Must be evaluated for clearance requirements through discussions with the utility provider and the Engineer. | N/A |
### Utility Depth

<table>
<thead>
<tr>
<th>Utility</th>
<th>Depth (To Top Of Utility)</th>
<th>Parallel Clearance</th>
<th>Crossing Clearance</th>
<th>Crossing Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular Towers</td>
<td>N/A</td>
<td>• 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.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
REFERENCES


CHAPTER 17
Streets
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17.0 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 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 direction 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 direction 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 [1]
- Access Management Guidelines [3]
- Accessible Design for the Built Environment [4]
- Bikeway Traffic Control Guidelines for Canada [6]
- Canadian Guide to Neighbourhood Traffic Calming [8]
- Canadian Roundabout Design Guide [9]
- City of Edmonton Complete Streets Design and Construction Standards [10]
- Traffic Bylaw 5590 [11]
- City of Edmonton Zoning Bylaw 12600
- Creating Safer Communities [12]
- Design Vehicle Dimensions for Use in Geometric Design [13]
- Grade Crossing Standards [16]
- Guide for the Design of Roadway Lighting [18]
- Human Factors Research in Highway Safety, Transportation Research Board
- Main Streets Guideline [21]
- Metric Curve Tables: Circular and Spiral Curve Functions for Layout Purposes [22]
- Pedestrian Crossing Control Guide [23]
- Roadside Design Guide [24]
- Separated Bike Lane Planning and Design Guide [25]
• Urban Bikeway Design, TAC
• Winter Design Guidelines [26]

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 practical 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 [14]. 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 direction 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.

Crossing warning measures that must, at minimum, be implemented at At-Grade crossings are defined in the Transportation Corridor & Operations Matrix in Chapter 1, General which defines 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 sightlines 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 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 feasible, the Designer must 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 feasible, 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 possible.

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 signals must be provided for roadways parallel to a center-running
LRT ROW. Left turn signals for roadways crossing an LRT ROW do not always require protected or
prohibited phasing. Overlapping left turns may be permitted in constrained corridors; however, split left
turn phasing will be required.
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), and Utility Complexes for scheduled and emergency maintenance and operational activities. Parking requirements are defined 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.

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.
REFERENCES


CHAPTER 18
Acronyms
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<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>Alberta Association of Architects</td>
</tr>
<tr>
<td>AAC</td>
<td>Accessibility Advisory Committee</td>
</tr>
<tr>
<td>AAR</td>
<td>Association of American Railroads</td>
</tr>
<tr>
<td>ABC</td>
<td>Alberta Building Code</td>
</tr>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>ACB</td>
<td>Axle Counter Blocks</td>
</tr>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>AEDARSA</td>
<td>Alberta Elevating Devices and Amusement Ride Safety Association</td>
</tr>
<tr>
<td>AFC</td>
<td>Alberta Fire Code</td>
</tr>
<tr>
<td>AFRRCS</td>
<td>Alberta First Responders Radio Communications System</td>
</tr>
<tr>
<td>AFF</td>
<td>Above Finished Floor</td>
</tr>
<tr>
<td>AFTC</td>
<td>Audio Frequency Track Circuits</td>
</tr>
<tr>
<td>AHJ</td>
<td>Authority Having Jurisdiction</td>
</tr>
<tr>
<td>AIM</td>
<td>Advanced Information Management</td>
</tr>
<tr>
<td>AIR</td>
<td>Air Systems Monitoring</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>APEGA</td>
<td>Association of Professional Engineers and Geoscientists of Alberta</td>
</tr>
<tr>
<td>API</td>
<td>Application Programmers Interface</td>
</tr>
<tr>
<td>APTA</td>
<td>American Public Transportation Association</td>
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<tr>
<td>AREMA</td>
<td>American Railway Engineering and Maintenance Association</td>
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<tr>
<td>ASCA</td>
<td>Alberta Safety Code Act</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigeration and Air Conditioning Engineers</td>
</tr>
<tr>
<td>ASPE</td>
<td>Standards American Society of Plumbing Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
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<td>ATM</td>
<td>Automatic Teller Machines</td>
</tr>
<tr>
<td>ATP</td>
<td>Automatic Train Protection</td>
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<td>ATS</td>
<td>Automatic Transfer Switch Monitoring</td>
</tr>
<tr>
<td>AW</td>
<td>Added Weight</td>
</tr>
<tr>
<td>AWG</td>
<td>American Wire Gauge</td>
</tr>
<tr>
<td>BCP</td>
<td>Best Common Practice</td>
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<tr>
<td>BDA</td>
<td>Bi-Directional Amplifier</td>
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<tr>
<td>BER</td>
<td>Bit-Error-Rate</td>
</tr>
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<td>BICSI</td>
<td>Building Industry Consulting Services International</td>
</tr>
<tr>
<td>BLC</td>
<td>Blacklight Compensation</td>
</tr>
<tr>
<td>Code</td>
<td>Abbreviation</td>
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<td>------</td>
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</tr>
<tr>
<td>BLR</td>
<td>Boiler Monitoring and Control</td>
</tr>
<tr>
<td>BLSR</td>
<td>Bi-directional Line Switched Ring</td>
</tr>
<tr>
<td>BMS</td>
<td>Building Management System</td>
</tr>
<tr>
<td>BWA</td>
<td>Balance Weight Assembly</td>
</tr>
<tr>
<td>CAB</td>
<td>Cold Air Blowers</td>
</tr>
<tr>
<td>CAC</td>
<td>City of Edmonton Corporate Accessibility Committee</td>
</tr>
<tr>
<td>CADD</td>
<td>Computer Aided Design &amp; Drafting</td>
</tr>
<tr>
<td>CAT</td>
<td>Category (designates cable category standard)</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge Coupled Device</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed Circuit Television</td>
</tr>
<tr>
<td>CDP</td>
<td>Central Distribution Panel</td>
</tr>
<tr>
<td>CEC</td>
<td>Canadian Electrical Code</td>
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<tr>
<td>CEF</td>
<td>Cable Exchange Forces</td>
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<td>Cable Loss Forces</td>
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<td>CLG</td>
<td>Cooling Systems Monitoring and Control</td>
</tr>
<tr>
<td>CoP</td>
<td>Communication on Progress</td>
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<tr>
<td>CMO</td>
<td>Carbon Monoxide Condition Monitoring</td>
</tr>
<tr>
<td>CPTED</td>
<td>Crime Prevention Through Environmental Design</td>
</tr>
<tr>
<td>CSA</td>
<td>Canadian Standards Association</td>
</tr>
<tr>
<td>CSDCS</td>
<td>Complete Streets Design and Construction Standards</td>
</tr>
<tr>
<td>CTC</td>
<td>Centralized Train Control</td>
</tr>
<tr>
<td>CUCM</td>
<td>Cisco Unified Communication Management</td>
</tr>
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<td>CWDM</td>
<td>Course Wave Division Multiplexing</td>
</tr>
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<td>CWI</td>
<td>Crossing Warning Indicator</td>
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<td>CWR</td>
<td>Continuous Welded Rail</td>
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<tr>
<td>D&amp;CS</td>
<td>City of Edmonton Design and Construction Standards</td>
</tr>
<tr>
<td>DA</td>
<td>Directory Access</td>
</tr>
<tr>
<td>DAS</td>
<td>Distributed Antenna System</td>
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<tr>
<td>DATP</td>
<td>Discrete Automatic Train Protection</td>
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<tr>
<td>DATS</td>
<td>Disabled Adult Transit Service</td>
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<td>DC</td>
<td>Direct Current</td>
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<tr>
<td>DDC</td>
<td>Direct Digital Control</td>
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<td>DLA</td>
<td>Dynamic Load Analysis</td>
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<tr>
<td>DLM</td>
<td>D.L. MacDonald</td>
</tr>
<tr>
<td>DMVPN</td>
<td>Dynamic Multipoint Virtual Private Network (DMVPN) technology</td>
</tr>
<tr>
<td>DQMP</td>
<td>Design Quality Management Plan</td>
</tr>
<tr>
<td>DSD</td>
<td>Design Services Document</td>
</tr>
</tbody>
</table>
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 System
ETSI  European Telecommunications Standards Institute
FAS  Fire Alarm System
FBS  Fixed Block System
FEP  Fluorinated Ethylene Propylene
FIR  Fire Suppression Systems Monitoring
FMR  Feeder Management Relay
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
GSC  Genetec Security Centre
GUI  Graphic User Interface
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>High Density Polyethylene</td>
</tr>
<tr>
<td>HEPA</td>
<td>High Efficiency Particulate Air</td>
</tr>
<tr>
<td>HID</td>
<td>High Intensity Discharge</td>
</tr>
<tr>
<td>HLC</td>
<td>Highlight Compensation</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
<tr>
<td>HTG</td>
<td>Heating Systems Monitoring and Control</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating Ventilation Air Conditioning</td>
</tr>
<tr>
<td>HWx</td>
<td>Heating Water Systems Monitoring and Control where “x” = system numbers</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IETF</td>
<td>Internet Engineering Task Force</td>
</tr>
<tr>
<td>IFC</td>
<td>Issued for Construction</td>
</tr>
<tr>
<td>IFT</td>
<td>Issued for Tender</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>LCP</td>
<td>Local Control Panel</td>
</tr>
<tr>
<td>LDAP</td>
<td>Lightweight Directory Access Protocol</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>LEED</td>
<td>Leadership in Energy and Environmental Design</td>
</tr>
<tr>
<td>LID</td>
<td>Low Impact Development</td>
</tr>
<tr>
<td>LOS</td>
<td>Level-of-Service</td>
</tr>
<tr>
<td>LRT</td>
<td>Light Rail Transit</td>
</tr>
<tr>
<td>LRV</td>
<td>Light Rail Vehicle</td>
</tr>
<tr>
<td>LSZH</td>
<td>Low-Smoke, Zero-Halogenated</td>
</tr>
<tr>
<td>LTG</td>
<td>Lighting System Monitoring and Control</td>
</tr>
<tr>
<td>MBR</td>
<td>Maximum Bit Rate</td>
</tr>
<tr>
<td>MC</td>
<td>Marshalling Cabinet Monitoring</td>
</tr>
<tr>
<td>MDP</td>
<td>Main Distribution Panel</td>
</tr>
<tr>
<td>MPA</td>
<td>Mid-Point Anchor</td>
</tr>
<tr>
<td>MPLS</td>
<td>Multi-Protocol Label Switching</td>
</tr>
<tr>
<td>MRC</td>
<td>Manual Route Clearance</td>
</tr>
<tr>
<td>MSE</td>
<td>Mechanically Stabilized Earth</td>
</tr>
<tr>
<td>MV</td>
<td>Medium Voltage</td>
</tr>
<tr>
<td>NAS</td>
<td>Network Attached Storage</td>
</tr>
<tr>
<td>NB</td>
<td>Northbound</td>
</tr>
<tr>
<td>NBC</td>
<td>National Building Code of Canada</td>
</tr>
<tr>
<td>NCF</td>
<td>Negative Circuit Feeder</td>
</tr>
<tr>
<td>NCR</td>
<td>Non-Conformance Report</td>
</tr>
<tr>
<td>NECB</td>
<td>National Energy Code of Canada for Buildings</td>
</tr>
</tbody>
</table>
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
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
PDDDM  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
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGS</td>
<td>Rail Ground Switch</td>
</tr>
<tr>
<td>ROW</td>
<td>Right-of-Way</td>
</tr>
<tr>
<td>RRS</td>
<td>Radio Repeater System</td>
</tr>
<tr>
<td>RSC</td>
<td>Rigid Steel Conduit</td>
</tr>
<tr>
<td>RSSI</td>
<td>Received Signal Strength Indicator</td>
</tr>
<tr>
<td>RTRC</td>
<td>Reinforced Thermosetting Resin Conduit</td>
</tr>
<tr>
<td>RTU</td>
<td>SCADA Remote Terminal Unit</td>
</tr>
<tr>
<td>SAN</td>
<td>Storage Area Network</td>
</tr>
<tr>
<td>SB</td>
<td>Southbound</td>
</tr>
<tr>
<td>SCA</td>
<td>SCADA System Alarm Monitoring</td>
</tr>
<tr>
<td>SCC</td>
<td>Switch Circuit Controller</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SCAT</td>
<td>Simple Catenary Auto Tension</td>
</tr>
<tr>
<td>SCN</td>
<td>Survey Control Network</td>
</tr>
<tr>
<td>SCP</td>
<td>Supervisory Control Panel</td>
</tr>
<tr>
<td>SEC</td>
<td>Security and Alarm Monitoring Systems</td>
</tr>
<tr>
<td>SEM</td>
<td>Sequential Excavation Method</td>
</tr>
<tr>
<td>SER</td>
<td>Signal Equipment Room</td>
</tr>
<tr>
<td>SFP</td>
<td>Small Form-Factor Pluggable</td>
</tr>
<tr>
<td>SFV</td>
<td>Smart Fare Validator</td>
</tr>
<tr>
<td>SFVM</td>
<td>Smart Fare Vending Machine</td>
</tr>
<tr>
<td>SIL4</td>
<td>Safety Integrity Level 4</td>
</tr>
<tr>
<td>SIP</td>
<td>Session Initiation Protocol</td>
</tr>
<tr>
<td>SLS</td>
<td>Serviceability Limit States</td>
</tr>
<tr>
<td>SMK</td>
<td>Smoke Control Monitoring and Control</td>
</tr>
<tr>
<td>SMP</td>
<td>Sump Monitoring</td>
</tr>
<tr>
<td>SNW</td>
<td>Track Snow Blower Monitoring and Control</td>
</tr>
<tr>
<td>SOP</td>
<td>Safe Operating Procedure</td>
</tr>
<tr>
<td>SORS</td>
<td>Sequential Occupancy Restoral System</td>
</tr>
<tr>
<td>SPK</td>
<td>Speaker</td>
</tr>
<tr>
<td>SPT</td>
<td>Space Temperature Monitoring</td>
</tr>
<tr>
<td>SRR</td>
<td>Signals Room Routers</td>
</tr>
<tr>
<td>SRS</td>
<td>Signals Room Switch</td>
</tr>
<tr>
<td>SSD</td>
<td>Surge Suppression Devices</td>
</tr>
<tr>
<td>STI</td>
<td>Speech Transmission Index</td>
</tr>
<tr>
<td>SUI</td>
<td>Sustainable Urban Integration</td>
</tr>
<tr>
<td>SUP</td>
<td>Shared Use Path</td>
</tr>
<tr>
<td>TAC</td>
<td>Transportation Association of Canada</td>
</tr>
</tbody>
</table>
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
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
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMS</td>
<td>Variable Message Sign</td>
</tr>
<tr>
<td>VNC</td>
<td>Virtual Network Computing</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over Internet Protocol</td>
</tr>
<tr>
<td>VOV</td>
<td>Verband Öffentlicher Verkehrsbetriebe</td>
</tr>
<tr>
<td>VPLS</td>
<td>Virtual Private LAN Service</td>
</tr>
<tr>
<td>VPRN</td>
<td>Virtual Private Routed Network</td>
</tr>
<tr>
<td>VRCE</td>
<td>Vehicle Running Clearance Envelope</td>
</tr>
<tr>
<td>VRF</td>
<td>Virtual Routing and Forwarding</td>
</tr>
<tr>
<td>WAP</td>
<td>Wireless Access Point</td>
</tr>
<tr>
<td>WBS</td>
<td>Wireless Base Station</td>
</tr>
<tr>
<td>WDM</td>
<td>Optical Wave Division Multiplexor</td>
</tr>
<tr>
<td>WSU</td>
<td>Wireless Subscriber Unit</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Access Design Guide</td>
<td>A City of Edmonton document that provides information on creating accessible environments, supported by City of Edmonton Policy C602.</td>
</tr>
<tr>
<td>Accessibility</td>
<td>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.</td>
</tr>
<tr>
<td>Ancillary Facilities</td>
<td>Buildings or structures that support the function and operation of the LRT System. These may include:</td>
</tr>
<tr>
<td></td>
<td>- Pedestrian overpass or underpass structures (pedways)</td>
</tr>
<tr>
<td></td>
<td>- Passenger shelter structures</td>
</tr>
<tr>
<td></td>
<td>- Structures containing mechanical, electrical, communications or other service equipment</td>
</tr>
<tr>
<td></td>
<td>- Traction Power Substations or Utility Complexes</td>
</tr>
<tr>
<td></td>
<td>- Signal equipment enclosures</td>
</tr>
<tr>
<td></td>
<td>- Transit Centre buildings (shelters)</td>
</tr>
<tr>
<td></td>
<td>- Parking areas (surface and in structure)</td>
</tr>
<tr>
<td>Application Logic</td>
<td>A collection of Boolean expressions and relationships which replicate relay logic circuits within a solid-state Vital Logic Controller.</td>
</tr>
<tr>
<td>At-Grade</td>
<td>The cross-sectional form of the Trackway where the elevation of the Trackway is at the same relative elevation as the adjacent ground level.</td>
</tr>
<tr>
<td>Authority Having Jurisdiction</td>
<td>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.</td>
</tr>
<tr>
<td>Barrier-Free</td>
<td>Absence of obstacles, allowing persons with physical, cognitive or sensory impairments safer or easier, access to pathways, open spaces, amenities, facilities, services, or activities.</td>
</tr>
<tr>
<td>Barrier-Free Design Guide</td>
<td>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.</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
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<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Block Signal</td>
<td>A Signal that governs the entrance to a Signal Block or Interlocking and conveys authority to proceed into the next Signal Block.</td>
</tr>
<tr>
<td>Bond</td>
<td>A metal conductor, usually copper, connecting two points of a conductive structure to equalize their electrical potential.</td>
</tr>
<tr>
<td>Building Management System (BMS)</td>
<td>Direct Digital Control system complete with hardware, software, and graphics for control of equipment, systems, and environment within a building or structure.</td>
</tr>
<tr>
<td>Call-on Signal</td>
<td>A Signal which conveys information about the status of a crossing warning system.</td>
</tr>
<tr>
<td>Canopy</td>
<td>The overhead covering or roof-like structure that provides shelter for Patrons on a Platform from rain, sun, or snow.</td>
</tr>
<tr>
<td>Catwalk</td>
<td>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.</td>
</tr>
<tr>
<td>Concourse</td>
<td>An intermediate area connecting a station Platform to a Street via stairs, escalators, or corridors.</td>
</tr>
<tr>
<td>Consist</td>
<td>One or more rail vehicles, at least one of which must be powered, forming a complete Train.</td>
</tr>
<tr>
<td>Contract Documents</td>
<td>Drawings, specifications and other documents that relate specifically to an individual project.</td>
</tr>
<tr>
<td>Contractor</td>
<td>An entity that is employed by the Engineer to construct LRT infrastructure. The Contractor may employ the Designer depending on the project delivery method.</td>
</tr>
<tr>
<td>Control Block</td>
<td>A section of Trackway consisting of one or more Signal Blocks bounded by Interlockings.</td>
</tr>
<tr>
<td>Crime Prevention Through Environmental Design (CPTED)</td>
<td>The science around the design and effective use of physical space to lead to a reduction in both the incidence and fear of crime.</td>
</tr>
<tr>
<td>Cross Bond</td>
<td>An electrical connection between parallel conductors of the Return Circuit intended to promote current balance between adjacent tracks and each running rail.</td>
</tr>
<tr>
<td>Cross-Connections</td>
<td>Tunnel segment between two structures, usually two tunnels. A Cross-Connection is used by ETS personnel and by LRV Passengers in an emergency.</td>
</tr>
<tr>
<td>Curvature Effect</td>
<td>Vehicle body overhang induced by a curve. This effect is considered</td>
</tr>
</tbody>
</table>
independently of other effects on the dynamic envelope.

**Design**
Production of 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.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>Elevated Station</td>
<td>A Station constructed above ground level. The LRT Trackway leading to and from an Elevated Station is located on an elevated guideway or structure.</td>
</tr>
<tr>
<td>Enclosed Canopy</td>
<td>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.</td>
</tr>
<tr>
<td>Engineer</td>
<td>The City of Edmonton’s LRT Expansion and Renewal Branch.</td>
</tr>
<tr>
<td>Exclusive Use Corridor</td>
<td>A corridor where LRT is the only transportation mode, such as in tunnels, elevated guideways and any other corridors with no crossings or interfaces.</td>
</tr>
<tr>
<td>Executive Software</td>
<td>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.</td>
</tr>
<tr>
<td>Facility Network</td>
<td>The BMS communication network linking all BMS controllers within a facility, and is on the same network as the Main Network but subgrouped for each facility.</td>
</tr>
<tr>
<td>Failsafe</td>
<td>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.</td>
</tr>
<tr>
<td>Feeder Switch</td>
<td>An electrical switch (which is normally left closed) that connects the power distribution cables to overhead catenary wires.</td>
</tr>
<tr>
<td>Floating Ground</td>
<td>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 earth.</td>
</tr>
<tr>
<td>Grade Separated</td>
<td>A cross-sectional form of Trackway located above or below the adjacent Transportation Corridor.</td>
</tr>
<tr>
<td>Human Factors Specialist</td>
<td>A specialist dealing with the application of information on physical and psychological characteristics to the design of devices and systems for human use.</td>
</tr>
<tr>
<td>Insulating Joint</td>
<td>A mechanical joint which electrically separates two adjacent structures or rails.</td>
</tr>
<tr>
<td>Integrated Hazard Analysis</td>
<td>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.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>-----------------------------</td>
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</tr>
<tr>
<td>Interlocking</td>
<td>An arrangement of Signals that allows the safe passage of one or more Trains through an arrangement of tracks while preventing conflicting movements.</td>
</tr>
<tr>
<td>Interlocking Signal</td>
<td>A Block Signal that governs Movement Authority through an Interlocking in addition to a Signal Block.</td>
</tr>
<tr>
<td>Kiss and Ride</td>
<td>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.</td>
</tr>
<tr>
<td>Light Rail Vehicle (LRV)</td>
<td>A high floor, single, bi-directional rail vehicle used to carry Passengers on the LRT System.</td>
</tr>
<tr>
<td>Line of Sight</td>
<td>An operational constraint where the Train Operator is solely responsible for the safe movement of the Train.</td>
</tr>
<tr>
<td>Load Flow Study</td>
<td>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.</td>
</tr>
<tr>
<td>LRT Controller</td>
<td>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.</td>
</tr>
<tr>
<td>LRT Right-of-Way (ROW)</td>
<td>LRT operating area containing the track, systems, Stations and Wayside equipment.</td>
</tr>
<tr>
<td>LRT System</td>
<td>The City of Edmonton’s high floor LRT network.</td>
</tr>
<tr>
<td>Mainline</td>
<td>Track constructed for the purpose of carrying revenue Passengers.</td>
</tr>
<tr>
<td>Mixed-Use</td>
<td>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.</td>
</tr>
<tr>
<td>Movement Authority</td>
<td>Operational permission for a Train to enter a designated area of the LRT Trackway.</td>
</tr>
<tr>
<td>Multi-Modal Station</td>
<td>A Station where transfer of Patrons from one mode of transportation to another such as bus transit, LRT or active modes occurs.</td>
</tr>
<tr>
<td>Non-Vital</td>
<td>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.</td>
</tr>
<tr>
<td>Office</td>
<td>Centralized Non-Vital systems for managing day to day LRT operations and maintenance activities at the LRT Operations Control Centre (OCC).</td>
</tr>
<tr>
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</tr>
<tr>
<td>Open</td>
<td>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.</td>
</tr>
<tr>
<td>Operational Headway</td>
<td>Intended headway based on operational scheduling.</td>
</tr>
<tr>
<td>Operator</td>
<td>The City of Edmonton’s Edmonton Transit Services Branch which both operates and maintains the LRT System.</td>
</tr>
<tr>
<td>Owner</td>
<td>The City of Edmonton.</td>
</tr>
<tr>
<td>Park and Ride</td>
<td>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.</td>
</tr>
<tr>
<td>Passenger</td>
<td>A Patron while in an LRV.</td>
</tr>
<tr>
<td>Patron</td>
<td>A user of the LRT System.</td>
</tr>
<tr>
<td>Patron Drop-off</td>
<td>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.</td>
</tr>
<tr>
<td>Platform</td>
<td>Portion of the Station directly adjacent to the Trackway where LRVs stop to load and unload Passengers.</td>
</tr>
<tr>
<td>Pocket Track</td>
<td>Track constructed for the propose of temporary storage, staging, and branching off the mainline track. Pocket track must be constructed to Mainline track standards.</td>
</tr>
<tr>
<td>Portable Operator Terminal</td>
<td>A laptop computer connected to the BMS at a controller</td>
</tr>
<tr>
<td>Project Development and Delivery Model (PDDM)</td>
<td>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.</td>
</tr>
<tr>
<td>Protective Ground</td>
<td>Temporary ground Designed for the grounding of electrical conductors during temporary circuit isolations.</td>
</tr>
<tr>
<td>Rail Bond</td>
<td>A conductor ensuring the electrical continuity of rails at a joint for the purpose of traction power return.</td>
</tr>
<tr>
<td>RAM Program Plan</td>
<td>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.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Refuge Zone</td>
<td>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.</td>
</tr>
<tr>
<td>Return Circuit</td>
<td>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.</td>
</tr>
<tr>
<td>Route Locking</td>
<td>Vital functionality ensuring that conflicting and opposing Train movements cannot occur within an Interlocking.</td>
</tr>
<tr>
<td>Sacrificial Anode</td>
<td>Metal, often zinc, which preferentially deteriorates when connected in a circuit to a metal structure.</td>
</tr>
<tr>
<td>Safety Certification</td>
<td>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.</td>
</tr>
<tr>
<td>Safety Critical</td>
<td>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.</td>
</tr>
<tr>
<td>Safety Critical Software</td>
<td>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.</td>
</tr>
<tr>
<td>Semi-Exclusive Corridor</td>
<td>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.</td>
</tr>
<tr>
<td>Service Vehicles</td>
<td>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.</td>
</tr>
<tr>
<td>Shared-Use Corridor</td>
<td>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.</td>
</tr>
<tr>
<td>Shop Track</td>
<td>Pit tracks or embedded tracks constructed within the building limits of storage and maintenance facilities.</td>
</tr>
<tr>
<td>Signal</td>
<td>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.</td>
</tr>
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</tr>
<tr>
<td>Signal Aspect</td>
<td>The visual appearance of a fixed Signal which conveys operational information.</td>
</tr>
<tr>
<td>Signal Block</td>
<td>A discrete section of railway track that is bounded by Block Signals.</td>
</tr>
<tr>
<td>Signal Indication</td>
<td>The meaning of a Signal Aspect, which conveys Movement Authority and related information to the Train Operator.</td>
</tr>
<tr>
<td>Signal System</td>
<td>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.</td>
</tr>
<tr>
<td>Speed Check</td>
<td>A device capable of stopping an LRV which is travelling faster than authorized at a discrete point and direction.</td>
</tr>
<tr>
<td>Station</td>
<td>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.</td>
</tr>
<tr>
<td>Stray Current</td>
<td>The small amount of current that flows through paths other than the intended main traction power system circuit.</td>
</tr>
<tr>
<td>Stray Current Mitigation Plan</td>
<td>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.</td>
</tr>
<tr>
<td>Stray Current Survey</td>
<td>Measurements and calculations to determine the effect of a project on Stray Current levels.</td>
</tr>
<tr>
<td>Street</td>
<td>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.</td>
</tr>
<tr>
<td>Structural Clearances</td>
<td>The minimum horizontal and vertical clearance requirements for Trackway elements.</td>
</tr>
<tr>
<td>Superelevation Effects</td>
<td>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.</td>
</tr>
<tr>
<td>Sustainable Urban Integration</td>
<td>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.</td>
</tr>
</tbody>
</table>
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.
<table>
<thead>
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<td>Universal Design</td>
<td>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.</td>
</tr>
<tr>
<td>Urban Corridor</td>
<td>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.</td>
</tr>
<tr>
<td>Urban Interface</td>
<td>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.</td>
</tr>
<tr>
<td>Urban Style</td>
<td>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.</td>
</tr>
<tr>
<td>Utility Complex</td>
<td>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.</td>
</tr>
<tr>
<td>Variable Frequency Drive</td>
<td>A device which changes the rotational speed of the motor of a piece of rotational equipment.</td>
</tr>
<tr>
<td>Vital</td>
<td>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.</td>
</tr>
<tr>
<td>Vital Logic Controller</td>
<td>A highly reliable and failsafe programmable logic controller and associated Vital input/output interfaces which is designed explicitly for railway signaling applications.</td>
</tr>
<tr>
<td>Voltage-Limiting Device</td>
<td>A protective device whose function is to prevent existence of high touch potential.</td>
</tr>
<tr>
<td>Wayside</td>
<td>Areas along the Trackway where LRT related systems and equipment may be placed.</td>
</tr>
<tr>
<td>Yard Track</td>
<td>Track that does not carry revenue Passengers and is used for Train storage and maintenance. Yard Track is designated by a Yard Limit sign.</td>
</tr>
</tbody>
</table>