Peninsula Corridor Joint Powers Board
1250 San Carlos Avenue
San Carlos, California 94070-1306

ELECTRIFICATION STANDARD

OVERHEAD CONTACT SYSTEM DESIGN CRITERIA

JANUARY 01, 2024
EDITION

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Revision History

January 01, 2024	New Edition

Note:

The content of Chapters 1, 21 and 22 of Caltrain Electrification Design Criteria have been revised from the original Peninsula Corridor Electrification Project (PCEP).

The content of Chapters 2 to 20 of Caltrain Electrification Design Criteria included in the original Peninsula Corridor Electrification Project (PCEP) are covered either by Caltrain Design Criteria (4th Edition) or under development.

Chapter 1 General

Acronyms

Caltrain	Peninsula Corridor Joint Powers Board Caltrain Service
mph	miles per hour

1.1 Design Criteria Overview

1.1.1 Purpose and Extent

This document establishes standard criteria, guidelines, and requirements for the design of infrastructure and systems elements in Caltrain Territories to be Electrified. Additional guidelines are required for the design of facilities of other owners/operations.

These criteria include design traction power supply systems, overhead contact system and traction power return system, grounding and bonding requirements, corrosion control, signaling and train control, yard signaling, electromagnetic compatibility and interface, supervisory control and data acquisition subsystems, communications, rolling stock–core systems interfaces and, safety and security.

The intended use of these criteria is for future design of Caltrain Electrification Projects, unless indicated otherwise.

1.1.2 Design Standard Classifications

The following terms are used to classify the criteria:

- "Recommended" – Standard to be equaled or exceeded where there are no major physical, cost, or schedule constraints. Designers should use "Recommended" values to the extent practical.
- "Minimum/Maximum" – Represent limits. Designers shall make every effort to avoid the use of minimum/maximum values. These values are acceptable where constraints make the use of "Recommended" values impracticable.
- "Shall" – Indicates mandatory requirement that must be strictly implemented. Waiver is permissible only under approval of design variance.
- "Should" – Indicates preferred course of action. Design variance is not required if it is not exercised.
- "May" – Indicates permissible course of action within the limits of the standards. Design variance is not required if it is not exercised.

1.1.3 Revisions

Revisions of these criteria, in part or in whole, will be issued by Caltrain or its representative.

1.1.4 Other Caltrain Electrification Standards:

The following documents may be considered with this Design Criteria:

- Caltrain Electrification Standard Specifications
- Caltrain Electrification Standard Drawings
- Caltrain CADD Manual
- California High-Speed Rail Authority and Federal Railroad Administration 2005 Final Program Environmental Impact Report/Environmental Impact Statement for the Proposed California High-Speed Train System.
- Bay Area to Central Valley Program Environmental Impact Report/Environmental Impact Statement

1.2 Basis of Design

The Caltrain Electrification system shall be designed as a 2 x 25 kV, 60 Hz autotransformer traction electrification system that shall meet the physical, functional, and performance requirements set out in this document and in the project specific Basis of Design as applicable.

1.3 Regulations, Codes, Standards, and Guidelines

The following sections list the system-wide, international, federal, state, and industry specific regulations, codes, standards, and guidelines that have been used in development of these criteria. In addition, the regulations, codes, standards, and guidelines pertaining to each area of design are listed in specific chapters. These lists are not all inclusive. It is the Designer's responsibility to determine additional regulations, codes, and standards that are applicable.

Additional, applicable requirements by authorities having jurisdiction over the design, construction, and operation of Caltrain's Right-Of-Way shall be identified and applied as required for approval from those authorities.

See General Provisions for precedence of Regulations, Codes, Ordinances, and Standards.

Unless a specific publication edition is identified, the latest edition at the time of the release of this document shall apply.

Deviations from the criteria stated herein require approval from Caltrain Engineering and their decisions regarding conflicts shall be final.

Federal and state regulations and codes govern passenger and freight rail systems in the U.S. These regulations are typically the basis of design and govern the operation of conventional rail networks and the operation of rail systems with speeds under 150 mph. Other regulations and codes apply to the design of Caltrain buildings and facilities and are not specific to Caltrain's system.

1.3.1 Federal and National Regulations and Codes

- Americans with Disabilities Act (ADA)
- Code of Federal Regulations (CFR), specifically Title 49 CFR Parts 200-299 and Title 28 part 36.
- U.S. Environmental Protection Agency (EPA) Laws, Regulations, Guidance and Dockets, and Executive Orders

1.3.2 State Regulations and Codes

- California Building Standards Code (CBSC), Title 24 of CCR
- California Business and Professions Code
- California Code of Regulations (CCR)
- California Public Utilities Commission (CPUC) General Orders (GO's)

1.3.3 Standards and Guidelines

Standards have been developed by governments, industries, and operators for design and construction to ensure consistency and compatibility among various elements of a rail system. In some cases, fulfillment of standards may be required to secure regulatory approvals from the U.S.

Army Corps of Engineers, Division of the State Architect, Office of the State Fire Marshall, California Coastal Commission, Caltrans, and other agencies and authorities.

Federal Standards and Guidelines

- Federal Railroad Administration (FRA) Standards and Guidelines
- Federal Emergency Management Agency (FEMA) Guidelines
- Federal Highway Administration (FHWA) Guidelines
- National Earthquake Hazards Reduction Program (NEHRP)
- U.S. Army Corps of Engineers Guidelines
- U.S. Bureau of Land Management Surveying Manual
- United States Geological Survey (USGS) Standards
- Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)
- National Electric Code (NEC)
- National Fire Protection Association (NFPA) Codes and Standards

State Standards and Guidelines

- California Disabled Accessibility Guidebook (CalDAG)
- California Seismic and Safety Commission Standards and Guidelines
- California Occupational Safety and Health Administration (Cal/OSHA) Standards
- California Department of Transportation (Caltrans) Standard Plans, Specifications, Manuals, and Guidelines
- Other Right of Way Publications

Industry Standards and Guidelines

- American Association of State Highway and Transportation Officials (AASHTO) Guidance
- American Concrete Institute (ACI) Building Code Requirements
- American Institute of Steel Construction (AISC) Steel Construction Manual
- American Plywood Association (APA)
- American Public Transit Association (APTA) Guidance
- American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering and Portfolio of Trackwork Plans
- American Railway Engineering and Maintenance of way Association (AREMA) Communications and Signal Manual
- American Society for Photogrammetry and Remote Sensing (ASPRS) Manual
- American Society for Testing and Materials (ASTM) Standards
- American Society of Civil Engineers (ASCE) Guidelines
- American Welding Society (AWS) Codes
- American National Standards Institute (ANSI) Standards
- American Standard Code for Information Interchange (ASCII)
- American Society Of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Guidelines

- American Society of Mechanical Engineers (ASME) Standards and Guidelines
- Underwriters Laboratories (UL) Standards
- Institute of Electrical and Electronics Engineers (IEEE) Standards
- Association of American Railroads (AAR) Standards

Other Jurisdictions

Additional regulations, codes, standards, and guidelines may need to be considered along with site-specific permit and operational requirements. The following are representative agencies, organizations and services that may have specific design standards and specifications, operational and facility requirements that may need to be considered in the design of Caltrain facilities.

- Air Quality Districts
- Bicycle Coalitions
- City, County, Municipal, Codes, and Ordinances
- City, County, Municipal Utilities Codes, and Standards
- Congestion Management Agencies
- County Transportation Authorities
- Departments of Public Works
- Fire Departments
- Police Departments
- Emergency Responders
- Union Pacific (UP) Railroad Engineering Standards
- Flood Control Districts

Passenger Rail and local Transit Agencies including but not limited to:

- Peninsula Corridor Joint Powers Board (Caltrain) Design Criteria and Engineering Standards
- Parks and Recreation Departments
- Public Utilities Commission(s)
- Regional Comprehensive Planning Agencies
- Regional Council of Governments
- Regional Environment Agencies and Commissions
- Regional Water Quality Control Boards
- School Districts
- Waste Management entities
- MUNI
- BART
- VTA
- AMTRAK
- ACE

1.4 Precedence of Conflicting Requirements

1.4.1 Precedence by Jurisdiction

This design criteria document is specifically applicable to Electric Traction (ET) facilities within Caltrain Right-Of-Way and on tracks on which Caltrain operates.

Where Caltrain operates within another (Third Party) railroad's or transportation's Right-Of-Way, the design requirements of Caltrain and the Third Party shall apply.

The design of facilities owned by a Third Party located outside Caltrain's Right-Of-Way shall comply with the requirements prescribed by the Third Party.

Where Third Party infrastructure is located within Caltrain's Right-Of-Way, the more stringent of the requirements shall apply as required to achieve concurrence of Caltrain and Third Party.

If Caltrain's requirements and the Third Party conflict, the requirements of the party owning the Right-of-Way shall apply.

1.4.2 Precedence by Type of Requirement

In general, applicable regulations and codes take precedence over standards and guidelines. In the case of differing values between the regulations, codes, standards, and guidelines the criterion followed shall be that which results in the satisfaction of all applicable requirements.

1.4.3 Precedence of Requirements

- See General Provisions for precedence of documents.
- See General Provisions for precedence of Design Criteria and Design Standards.

1.5 General Design Parameters

1.5.1 Units of Measurement

Caltrain's system shall be based on U.S. Customary Units, defined by the National Institute of Standards and Technology (NIST). This is consistent with guidelines prepared by Caltrans.

Design and construction drawings shall be developed in accordance with Caltrain's CADD Manual.

1.5.2 Milepost and Stationing

Milepost and stationing shall be as defined in Track Charts and Contract Drawings.

1.5.3 Design Variances

Approved design variances are required for design elements that do not meet the limiting (maximum/minimum) design criteria. Requests for variances to design criteria shall follow the process set forth in Design Variance Request Process.

Design variances and exceptions to a Third Party's design standards shall follow the Third Party's design exception process.

Where a design variance is required for both Caltrain and Third Party, the design exception process for both entities shall be followed.

1.5.4 Professional Licensing Requirement

Documents such as drawings, specifications, and calculations intended for the construction of Caltrain facilities shall be prepared under the supervision and approval of a licensed professional in accordance with the requirements of Title 16 of the CCR and shall be subject to the limitations of the licensing laws of the state of California.

1.5.5 Third Party Facilities

Unless otherwise stated in the contract documents, the design, construction, replacement or alteration of Third Party facilities shall be done in-kind and in conformance with the published standards of the authority having jurisdiction.

1.6 Design Life

Design life for Caltrain's system infrastructure and systems elements are presented in Table 1-2.

These values are intended as baseline requirements for use in defining and assessing design and development standards and requirements, alternative materials and designs, and operational and maintenance activities.

Table 1-2: Design Life

Systems Infrastructure	Design Life
Traction Power Systems, including: Traction power supply system (TPS) (Future) Overhead contact system (OCS) support structures and conductors, with the exception of the contact wire, the life of which is dependent upon the number of pantograph passes. Grounding, bonding, and lightning protection system	40 years
Signaling, Train Control and Communications System, including (Future): PTC systems Yard signal systems and their subsystems Equipment and supporting cabling Highway grade crossing warning equipment Supervisory Control and Data Acquisition Communications wired and wireless data transport systems Communications administrative, control and timing systems Communications safety, security and fire detection systems Communications copper and fiber optic cable infrastructure and associated equipment	30 years
Other technology-based systems (Future): Equipment and non-safety critical microcontrollers, computers, software and similar commercial off-the-shelf (COTS) equipment	10 years

1.7 Standardization

Design shall use standard materials and equipment where possible. Standardization ensures ease of procurement and inventory management, minimizes staff training, optimizes maintenance, and avoids long lead times for materials, equipment, and components.

Equipment and materials shall meet industry standards, be available off the shelf, and supplied by established manufacturers. Selection of equipment and materials shall consider long-term costs, ease of construction and maintenance, and readily available technical support.

1.8 Durability

Design shall assess potential for deterioration of materials and assemblies, including deterioration specific to exposure to the environment. Materials and detail assemblies shall be durable with minimal maintenance and repairs throughout their design life. For surface and assembly for which appearance is important, durability shall include maintenance required to preserve appearance. Design shall take into account the following aspects of durability:

- Control of moisture
- Control of corrosion (including material compatibility)
- Control of ultraviolet light exposure
- Control of exposure to industrial and vehicular pollution
- Minimize damage from wear and tear
- Ease of repair
- Minimize risk by using theft deterrent materials and configurations

1.9 Noise Limitation

Noise from construction and operation of Caltrain's system and ancillary sources shall not exceed limits defined in the following:

- Caltrain Program and Project-specific Environmental Impact Report/Environmental Impact Statement
- Applicable noise laws and regulations
- Standard Specifications

1.10 Sustainability

1.10.1 Demonstration of High Performance Design

Traction power facilities shall be designed in accordance with all applicable CalGreen Code mandatory measures and the voluntary measures identified in Section 1.10.4 below, and any applicable local Green Building Ordinances. The Designer shall develop a project specific sustainability goal through analysis and submit for Caltrain Engineering review. The goal for traction power facilities is to optimize the design in regard to site design, energy, water, materials use, indoor air quality, construction practices, and management. A means to demonstrate this optimization may be to use the Leadership in Energy and Environmental Design (LEED), the Living Buildings Challenge, The Institute for Sustainable Infrastructures Envision System or other appropriate assessment methodology.

1.10.2 Water Conservation

Caltrain Electrification Projects shall incorporate water conservation and efficiency features and operating procedures in all planning, procurement, design, construction, operations, and maintenance of facilities. The goal for facilities is, where appropriate to the climate, to work toward potable water self-sufficiency through consumption reduction, recycling, and on-site capture and storage. Stormwater should be either managed onsite to supply the facility's internal water demands and landscaping, or released for management through acceptable natural time-scale surface flow, groundwater recharge, agricultural use or adjacent building needs.

1.10.3 Energy Conservation

Caltrain Electrification Project shall incorporate energy conservation and efficiency features and operating procedures in all planning, procurement, design, construction, operations, and maintenance of facilities. Caltrain Electrification Projects shall, at a minimum, use energy conservation and efficiency guidelines in applicable CalGreen Code mandatory measures and the specific voluntary measures identified in Section 1.10.4 below.

1.10.4 Specific CalGreen Code Voluntary Measures

The following CalGreen Code Voluntary Measures shall be considered mandatory.

<u>Planning and Design</u>

A5.106.3 Low impact development (LID). Reduce peak runoff in compliance with Section A5.106.1. Employ at least two of the following methods or other best management practices to allow rainwater to soak into the ground, evaporate into the air or collect in storage receptacles for irrigation or other beneficial uses. LID strategies include, but are not limited to:

1. Bioretention (rain gardens);
2. Cisterns and rain barrels;
3. Green roof meeting the structural requirements of the building code;
4. Roof leader disconnection;
5. Permeable and porous paving;
6. Vegetative swales and filter strips; tree preservation; and
7. Volume retention suitable for previously developed sites.

A5.106.7 Exterior wall shading. Meet requirements in the current edition of the California Energy Code and comply with either Section A5.106.7.1 or A5.106.7.2 for wall surfaces. If using vegetative shade, plant species documented to reach desired coverage within 5 years of building occupancy.

A5.106.11 Heat island effect. Reduce nonroof heat islands by Section A5.106.11.1 and roof heat islands by Section A5.106.11.2.

- A5.106.11.1 Hardscape alternatives. Use one or a combination of strategies 1 and 2 for 50 percent of site hardscape or put 50 percent of parking underground.

1. Use light colored materials with an initial solar reflectance value of at least .30 as determined in accordance with American Society for Testing and Materials (ASTM) Standards E1918 or C1549.
2. Use open-grid pavement system or pervious or permeable pavement system.

- A5.106.11.2 Cool roof for reduction of heat island effect. Use roofing materials having a minimum aged solar reflectance and thermal emittance complying with Sections A5.106.11.2.1 and A5.106.11.2.2 or a minimum aged Solar Reflectance Index (SRI) complying with Section A5.106.11.2.3 and as shown in Table A5.106.11.2.2 for Tier 1 or Table A5.106.11.2.3 for Tier 2.

  Exceptions:

  1. Roof constructions that have a thermal mass over the roof membrane, including areas of vegetated (green) roofs, weighing at least 25 pounds per square foot.
  2. Roof area covered by building integrated solar photovoltaic and building integrated solar thermal panels.
     - A5.106.11.2.1 Solar reflectance. (see technical specifications in code)
     - A5.106.11.2.2 Thermal emittance. (see technical specifications in code)
     - A5.106.11.2.3 Solar reflectance index alternative. (see technical specifications in code)
- A5.106.11.3 Verification of compliance. If no documentation is available, an inspection shall be conducted to ensure roofing materials meet cool roof aged solar reflectance and thermal emittance or SRI values.

Energy Efficiency

A5.203.1 Energy efficiency.

- A5.203.1.1.1 Outdoor lighting. Newly installed outdoor lighting power shall be no greater than 90 percent of the Title 24, Part 6 calculated value of allowed outdoor lighting power.
- A5.203.1.2.2 Tier 2. Buildings complying with the second level of advanced energy efficiency shall have an Energy Budget that is no greater than indicated below, depending on the type of energy systems included in the building project. If the newly constructed building, addition or alteration does not include indoor lighting or mechanical systems, then no additional performance requirements above Title 24, Part 6 are required.
  1. For building projects that include indoor lighting or mechanical systems, but not both: No greater than 90 percent of the Title 24, Part 6, Energy Budget for the Proposed Design Building as calculated by compliance software certified by the Energy Commission.
  2. For building projects that include indoor lighting and mechanical systems: No greater than 85 percent of the Title 24, Part 6, Energy Budget for the Proposed Design Building as calculated by compliance software certified by the Energy Commission.

Material Conservation and Resource Efficiency

Where practicable: A5.405.1 Regional materials. Compared to other products in a given product category, select building materials or products for permanent installation on the project that have been harvested or manufactured in California or within 500 miles of the project site.

1. For those materials locally manufactured, select materials manufactured using low embodied energy or those that will result in net energy savings over their useful life.
2. Regional materials shall make up at least 10 percent, based on cost, of total materials value.

3. If regional materials make up only part of a product, their values are calculated as percentages based on weight.
4. Provide documentation of the origin, net projected energy savings, and value of regional materials.

Where practicable: A5.405.2 Bio-based materials. Select bio-based building materials and products made from solid wood, engineered wood, bamboo, wool, cotton, cork, straw, natural fibers, products made from crops (soybased, corn-based) and other bio-based materials with at least 50 percent bio-based content.

- A5.405.2.1 Certified wood. Certified wood is an important component of green building strategies and the California Building Standards Commission will continue to develop a standard through the next code cycle.
- A5.405.2.2 Rapidly renewable materials. Use materials made from plants harvested within a 10-year cycle for at least 2.5 percent of total materials value, based on estimated cost.

Where practicable: A5.405.3 Reused materials. Use salvaged, refurbished, refinished or reused materials for a minimum of 5 percent of the total value, based on estimated cost of materials on the project. Provide documentation as to the respective values.

Where practicable: A5.405.4 Recycled content. Use materials, equivalent in performance to virgin materials, with a total (combined) recycled content value (RCV) of:

- Tier 2. [BSC] The RCV shall not be less than 15 percent of the total material cost of the project.
- Note: use the equations in the subsections for calculating total materials cost, recycled content, RCV of materials and assemblies, and total RCV.

Where practicable: A5.405.5 Cement and concrete. Use cement and concrete made with recycled products and complying with sections A5.405.5.1 – A5.405.5.3.

END OF CHAPTER

Chapter 21 Overhead Contact System and Traction Power Return System

Acronyms

ACSR	Aluminum Conductor Steel Reinforced
ATF	Autotransformer Feeder
EMC	Electromagnetic Compatibility
CALTRAIN	Peninsula Corridor Joint Powers Board Caltrain Service
NESC	National Electrical Safety Code
OCS	Overhead Contact System
PS	Paralleling Station
SCADA	Supervisory Control and Data Acquisition
TPSS	Traction Power Substation
SWS	Switching Station
TES	Traction Electrification System
TPF	Traction Power Facility

21.1 Scope

These criteria detail the overhead contact system (OCS), and the traction return system, including the parallel Autotransformer Feeders (ATF).

The overhead catenary conductors and support configurations shall be engineered to suit the operation of vehicles at speeds of up to 79 mph over the mainline portions of the rail system. Due to the potential future interaction with the proposed California High Speed Rail, the OCS shall be designed to accommodate the future 110 mph speed requirements.

The pantograph security, current collection, and phase break length shall be determined based on the pantograph characteristics requirements of AREMA Manual for Railway Engineering Chapter 33 Section 8.2.

The OCS design shall avoid locating down guys, overlaps, phase breaks, weights, motorized disconnect switches and other OCS equipment on station platforms, grade crossings and other areas accessible to the public. Down guys shall be designed to be parallel to the track.

The OCS Designer shall work with the Signal Designer in locating or relocating signal structures. Signal sighting distances shall be taken into account when OCS poles and/or supporting structures are designed and located.

21.1.1 OCS

The OCS is a system in which electrical conductors are supported aerially above the electrified tracks, generally by means of insulators and appropriate mechanical support arms or brackets, and which supplies electrical energy from the traction power supply facilities to rail mounted, electrically-powered vehicles through onboard, roof-mounted current collection equipment (pantographs).

The OCS comprises the following:

- All overhead wiring, including the messenger wires, feeder wires, and contact wires, mounted on OCS support structures or brackets
- The foundations, supporting structures, and any components supporting, registering, terminating or insulating the conductors
- Insulators, neutral-sections, auto-tensioning devices, and other overhead line hardware and fittings
- Equipment mounted on the supports for feeding, switching, detection or protection (including but not limited to hangers, manual and/or motor operated disconnect switches, section insulators, section phase breaks, conductor termination and tensioning devices, downguys, and other overhead line hardware and fittings)

21.1.2 Traction Return System

The traction return system is the means by which traction current is returned from the wheel-sets of traction units to the traction power facilities of the electrified railway, comprising the ATF (due to the configuration of the autotransformer connections), the grounded running rails, aerial static wires, and buried ground conductors, together with all return current bonding and grounding interconnections. Grounding and bonding and lightning protection for the electrified railway is covered in the Grounding and Bonding Chapter.

21.2 Regulations, Codes, Standards, and Guidelines

21.2.1 Refer to the General Chapter for requirements pertaining to regulations, codes, standards and guidelines.

- American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering, 2014, Chapter 33 Electrical Energy Utilization
- European Committee for Electrotechnical Standardization (CENELEC) Standards
  - EN 50119, 2001, Electric Traction Overhead Contact Lines
  - EN 50122-1 Part 1, 1998, Protective Provisions Relating to Electrical Safety and Earthing
  - EN 50124-1, 2001, Insulation Coordination: Part 1 – Basic Requirements
  - EN 50149, 2001, Electric Traction: Copper and Copper Alloy Grooved Contact Wires
  - EN 50317:2002 Railway applications. Current collection systems.
- California Code of Regulations (CCR) Title 8, Division 1, Chapter 4, Subchapter 5: Electrical Safety Orders
- Institute of Electrical and Electronics Engineers (IEEE)
  - IEEE 80, 2000, Guide for Safety in AC Substation Grounding
  - IEEE 142, 1991, Recommended Practice for Grounding of Industrial and Commercial Power Systems
- California Public Utilities Commission (CPUC) General Orders (GOs)
  - CPUC GO 26-D, 1981, Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structure Parallel Tracks, Crossings of Public Roads, Highways and Streets
  - CPUC GO 95, 2015, Rules for Overhead Electric Line Construction
  - CPUC GO 118, 1963, Regulations Governing the Construction, Reconstruction, and Maintenance of Walkways Adjacent to Railroad Trackage and the Control of Vegetation Adjacent Thereto.
  - CPUC GO 143-B, 2000, Safety Rules and Regulations Governing Light Rail Transit
- Technical Specification for Interoperability (TSI) Energy, 2008, Technical Specifications for the Interoperability of Electrical Energy Subsystems
- IEEE C2 - National Electrical Safety Code (NESC) – Although not adopted in California, used as a guide.

21.3 Definitions

Agency - The railroad or other jurisdictional entity that is responsible for the operation and maintenance of the railroad.

Autotransformer Feeder (ATF) – The ATF is a paralleling 25kV conductor which together with the 25kV OCS conductor forms the 50kV distribution system along the railway. The parallel ATF is connected via circuit breakers and disconnect switches to one terminal of a Main Power Transformer (MPT) and secondary winding on the Autotransformer (AT) in the TPF's.

Barrier - Equipment provided to prevent entry by an unauthorized person to a restricted area, structure or building, which also provides physical protection against direct contact with energized parts from non-normal directions of access.

Bond - A bond is an electrical connection from one conductive element to another for the purpose of maintaining a common electrical potential (equi- potential).

Bonding Conductor - A conductor for ensuring equi-potential bonding.

Catenary – An assembly of overhead wires consisting of, as a minimum, a messenger wire, carrying vertical hangers that support a solid contact wire (which is the contact interface with operating electric train pantographs), and which supplies power from a central power source to electrically-powered rail vehicles.

Catenary Feeder (parallel) – An energized conductor (25 kV nominal) emanating from the Catenary bus at a TPF through a circuit breaker and disconnect switch and supported on the same structures as, and parallel with the OCS to feed sections of Catenary remote from the TPF.

Contact Wire – A solid grooved, bare aerial, overhead electrical conductor of an OCS that is suspended above the rail vehicles and which supplies the electrically powered vehicles with electrical energy through roof-mounted current collection equipment (pantographs) and with which the current collectors make direct electrical contact.

Collector Head - That part of the pantograph which runs under and in contact with and collects current from the overhead contact wire or conductor rail.

Cross Bond - An electrical bond that interconnects the running rails which, in signaled territory, must be connected through impedance bonds.

De-energized (Apparently Dead) - Electrical apparatus, such as overhead wires, substation conductors, cables, switches and circuit breakers when disconnected from an electrical power source(s), but not grounded. NOTE: Dangerous to life until properly grounded

Direct Contact - Contact with energized parts.

Direct Feed System - A traction power feeding system in which the transformers are fitted with a single secondary winding having two terminals. One terminal is connected to the running rails/ground and the other to the catenary conductors over the tracks.

Direct Traction System Grounding - The direct connection between conductive parts and the traction system ground. Note: Grounding via impedance bonds, required by reason of signaling system track circuit considerations, is considered to be direct grounding.

Electrical Section or Feed Section - The section between the phase break of the traction power substation and the phase break of the adjacent switching station that is normally fed by one main transformer of the substation.

Elementary Electrical Section – The smallest section of the OCS power distribution system that can be isolated from other sections or feeders of the system by means of disconnect switches and/or circuit breakers.

Effectively Grounded - Intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current- carrying capacity to limit the build-up of voltages to levels below which undue hazards to persons or to connected equipment may result.

Energized (Live-dangerous to life) Part - An energized part is a conductor or conductive part that is energized under normal service conditions but does not include the running rails or parts connected to them. Energized parts include roof-mounted equipment on electric vehicles, such as pantographs, train line conductors, and resistor units. The full length of insulators connected to energized parts shall be classified as energized when considering electrical clearance requirements.

Fault Condition - The presence of an unintended and undesirable conductive path in an electric power system.

Grounding Conductor - A conductor that is used to connect equipment or wiring systems to a ground electrode or ground grid.

High Voltage (HV) - A nominal voltage of 600 Volts or more.

Leakage Current - A current that flows to ground or to extraneous conductive parts, following a path or paths other than the normal intended path, but which is not of sufficient magnitude to create a fault.

Messenger Wire – In catenary construction, the OCS Messenger Wire is a longitudinal bare stranded conductor that physically supports the contact wire or wires either directly or indirectly by means of hangers or hanger clips and is electrically common with the contact wire(s).

Metal-to-Metal Touch Voltage - The difference in electrical potential between metallic objects or structures that may be bridged by direct hand-to-hand or hand-to-feet contact.

Non-Current Carrying Parts - Metallic parts within Caltrain's right-of-way which do not normally carry load currents or return currents.

Paved Areas - In selected areas of maintenance facilities, yards and shops, the trackway may be paved to the upper level of the running rails to provide for the crossing of maintenance vehicles over the tracks and under the overhead conductors.

Rail Joint Bond - A conductor that ensures the electrical continuity of a running rail at an uninsulated, bolted rail joint.

Rail Potential - The voltage at the rails with respect to ground due to traction return or fault current flowing in the rails and the impedance of the rails to ground.

Rail to Ground Impedance - The electrical impedance between the running rails and the earth.

Railroad or Railway Environment - The area adjacent to the running rails that is subject to the noise, vibration and air pressure of trains operating at high speed, and to the effects of the voltages, currents and electric fields associated with a 25 kV AC Traction Electrification System (TES).

Rake - A preset lean of an OCS pole from vertical.

Regenerative Braking - A system in which the drive motors of the electric vehicles operate as generators and provide dynamic braking of the vehicle, while at the same time returning power to the OCS that can be used by receptive vehicles on the system or can be returned to the utility at the traction power substations.

Return Cable - A conductor that forms part of the TES return circuit, and which connects the rest of the return circuit to the substation.

Right of Way Classification - Right-of-Way (ROW) classifications are defined in CPUC GO No. 143-B Rule 9.04

- Semi-Exclusive - Right-of-Way with at-grade crossings, protected between crossings by a fence or substantial barrier, as appropriate to the location.

Running Rails - The steel rails on which the rail vehicles run and which, in an electrified system, form part of the traction return circuit. The running rails may also be used for signal system track circuits, in which case special measures must be implemented to permit joint use with electrification.

Screen - A barrier that prevents unintentional direct contact with energized parts but will not totally prevent direct contact by deliberate action.

Sectionalization - Separation of the distribution system into electrical sections to limit the length of the track to be de-energized following fault, or for system maintenance.
Sectionalizing can be performed at substations, paralleling stations and switching stations, as well as at interlockings where crossovers and turnouts are installed.

Short Circuit - A conductive path between energized and grounded components which may result in a high fault current. Note: Any such conductive path whether between conductors or between a conductor and ground is regarded as a short circuit.

Short Circuit, Current, or Fault Current - The electric current flowing through the short circuit or fault path.

Standing Surface - Any point on a surface where people may stand or walk.

Static Wire – A wire, usually installed aerially adjacent to or above the catenary conductors and autotransformer feeders, that connects OCS supports collectively to ground or to the grounded running rails to protect people and installations in case of an electrical fault. In an AC electrification system, the static wire forms a part of the traction power return circuit and is connected to the running rails via impedance bonds at specific intervals and to the traction power facility ground grids. If mounted aerially, the static wire may also be used to protect the OCS against lightning strikes. It is sometimes termed "aerial ground wire."

Step and Touch Potential or Voltage - Refers to Metal-to-Metal or metal to ground or grounded structure Touch Voltage, and Step Voltage.

Stray Current (Leakage Current). - A current which follows a path or paths other than those intended.

Supports - The structural elements that support the conductors and their associated line hardware and insulators in an OCS.

Surge Arrester or Surge Suppressor - A protective device for limiting surge voltages on equipment by discharging or by-passing surge current; it limits the flow of power follow- on current to ground and is capable of repeating these functions.

Traction Electrification System (TES) - The combination of equipment that supplies power to electric trains, including the traction power system (TPS) and the overhead contact system (OCS).

Traction Power Substation (TPSS) - An electrical installation that supplies traction power to the OCS and at which the voltage of the primary utility supply system is transformed to the OCS voltage.

Traction Rail Return Current - In an autotransformer 3-wire distribution system, most of the OCS load current is carried by the OCS and ATF conductor. The residual "return" current is carried by the rail/static wire/earth "rail return system".

Traction System Ground - The traction system ground consists of the running rails, the aerial static wires and all conductive parts connected thereto, and which are solidly connected to ground.

Traction System Grounding - Connection between non-energized metallic parts and the traction system ground.

Tunnel Ground - The electrical interconnection of the reinforcing steel in reinforced concrete tunnels and, in the case of other modes of construction, the conductive interconnection of the metallic parts of the tunnel.

Voltage-limiting Device - A protective device which operates to prevent the permanent existence of a dangerously high step or touch voltage.

21.4 Overhead Contact System Description and General Performance Requirements

In order to minimize the number of substations and Electromagnetic Compatibility (EMC) problems along the alignment, the line is fed by a 2x25 kV, 60 Hz autotransformer power supply system, utilizing traction power substations (TPSS), a switching station (SWS) and paralleling stations (PS).

21.4.1 Station Spacing

The TPSS is connected to HV utility supplies and spaced approximately every 30 miles, while the Switching Station (SWS) is spaced at approximately mid distance between TPSS, i.e., at about 15 miles from each TPSS, and the Paralleling Stations (PS) are spaced at approximately 5-mile (8 km) intervals. At the PS and SWS locations, the autotransformers parallel the Track MT-1 and Track MT-2 power supplies and balance the two 25 kV supplies (longitudinal parallel ATF and catenary) with respect to each other tending to direct much of the OCS load current to the ATF conductors, thereby reducing the return current in the rail return system. The OCS supports voltage variations in accordance with IEC 60850 "Supply Voltages of Traction Systems", as given in Table 21-1.

Table 21-1: Traction Power System Voltages

Voltage Condition	Symbol	Voltage
Operating nominal system voltage		25.0 kV
Highest permanent voltage	Umax1	27.5 kV
Highest non-permanent voltage	Umax2	29.0 kV

Lowest permanent voltage	Umin1	19.0 kV
Lowest non-permanent voltage	Umin2	17.5 kV

In addition, the maximum short circuit current is 15 kA for protection measurement purpose and accordingly for specification of the electrical equipment. At all traction power supply stations, the center tap of the respective supply transformer secondary and auto-transformer windings is connected to and referenced to the running rails, which will nominally be at ground potential.

21.4.2 OCS

The OCS provides electric traction power to the pantographs of the electric trains using the route and is configured as a 25 kV-0-25 kV arrangement with the catenary at a nominal voltage of 25 kV to ground and the longitudinal parallel ATF also at a nominal voltage of 25 kV to ground, but in phase opposition to the catenary. There is a 180 degree phase difference between the voltages of the parallel ATF's and the OCS, giving a 50 kV phase-to-phase voltage difference between these conductors. This phase difference between the parallel OCS serves to mitigate the EMI from the OCS load current.

The OCS shall transfer electric power from the Traction Power Substations to the trains under all operating conditions and shall provide for reliable operation under the environmental conditions detailed in Section 21.5.

Except at Phase Breaks, the OCS shall provide for uninterrupted traction power collection at the maximum operating speed of 110 mph. To allow bi-directional working, enabling trains to continue operation under emergency conditions and to facilitate routine OCS maintenance, the OCS shall be divided into electrical sections and sub-sections.

The OCS shall be sectionalized as indicated on the drawings and in Section 21.12 below. To facilitate operations and maintenance activities, the OCS shall typically be equipped with non-load break motor operated disconnect switches at feeding points, which can be operated both locally on site and remotely through a supervisory control and data acquisition (SCADA) system. The switches shall be fitted with OCS voltage detection circuitry that will provide remote monitoring of the system.

The OCS phase break arrangements shall be located at the SWS and at the TPSS's to electrically separate two successive catenary electrical sections fed from different 25 kV AC sources; i.e., not of the same phase. The electric trains shall pass through each phase break arrangement without establishing an electrical connection between the successive electrical sections which are fed from different phases. This shall be achieved at the designated maximum operating speed with the train pantographs raised and in contact with overhead contact wire, but with the pantograph breakers off.

Rail Return shall primarily be through the running rails, but a Static Wire (ground wire) shall be provided that interconnects all OCS support structures (poles, portal structures, wall brackets, tunnel drop pipes, etc.) which shall be connected via impedance bonds to the running rails and to the ground grid at each traction power facility (TPF).

Other cross-bonding connections may be required to minimize rail potential rise, and the frequency and location of these connections and of the impedance bonds shall be determined under the TP system design and coordinated with the Signal System design. Refer to the Grounding and Bonding Requirements chapter.

In electrical sections remote from sections in which trains are operating, the parallel ATF effectively carries much of the traction load current and minimizes the amount that flows through the rails and static wires, normally designated as the "rail return system". For a more comprehensive description of the traction power supply system and its associated facilities, refer to the Traction Power Supply System Chapter. Environmental Conditions and Climatic Loading Requirements Information on climatic and environmental conditions in the corridor is given in the General Chapter.

21.4.3 Factors of Safety

The OCS components and assemblies shall be designed to achieve safety factors of not less than the following minimum values under all loading conditions defined in these criteria:

Table 21-2 Minimum Safety Factors for OCS

Element of Overhead Contact System	Minimum Safety Factor
Messenger wire and contact wire, and their terminations, splices and fasteners (except tie wires)	2.0
Worn contact wire (maximum 30% worn)	1.6
All other aerial conductors and wires	2.5
Down guys, span guys, balance weight support wires and their terminations	2.5
Glass, porcelain and synthetic insulators	2.5
Pins, shackles, swivels, hinges, brackets, and attachments	2.5
Metallic pipes, struts, rods, clamps and castings	2.5
Poles against bending or twisting	2.0
Pole and down guy foundations against displacement and rotation	2.0

The OCS conductor analysis shall be based on a worst-case assumed contact wire wear of 30%. All structural components, including foundations, poles, guys and other structural components, shall achieve the required safety factors in accordance with CPUC G.O. No. 95 standards, AISC, ACI and NESC guidelines, supplemented by the requirements specified herein.

21.5 Environmental Conditions and Climatic Loading Requirements

The OCS shall be designed on a system-wide basis to provide reliable operation under the following environmental and climatic conditions:

21.5.1 Humidity

The OCS shall operate without failure or deterioration in all humidity conditions found in California. These include 100 percent humidity, rain, heavy fog and salt-laden atmospheres, and 100 percent humidity in tunnels. These conditions prohibit the use of weathering steel (ASTM A588) in poles and other structural elements and hardware.

21.5.2 Ice

In G.O. No. 95 the Light Loading Condition in the parts of California where the elevation above sea level is 3000 feet or less has no ice loading requirement. Although not adopted in the State of California, Table 250-1 and Figure 250-3(a) of the National Electrical Safety Code (NESC) also indicate a 0" uniform ice thickness. Therefore, the OCS design shall not consider ice loading.

21.5.3 Wind

The ASCE Standard “Minimum Design Loads for Building Structures” defines the basic wind speed corresponding to the wind load for wind force resisting structures as a 3 second gust speed at 33 feet (10.06 m) above ground for open terrain, Exposure C, associated with an annual probability of 0.02 (50 year mean recurrence interval) of being equaled or exceeded. This basic wind speed, in accordance with Figure 6-1 of the ASCE Standard, is Vbws = 85 mph (38 m/s) for the State of California. This 3 second gust speed corresponds to a mean maximum hourly wind speed of [Vbws/1.52 =] 56 mph (25 m/s) approximately. In accordance with Section 4.2.2 of Chapter 33 of the AREMA Manual, two different wind speeds, the operational wind speed and the design wind speed shall be used for OCS design:

The operational wind speed shall be used to compute catenary support loading, catenary wire displacement for pantograph security, and permissible maximum span lengths, and will be taken as Vop = 55 mph (24.5 m/s).

The design wind speed shall be used to determine the ultimate strength requirements of the OCS and will be taken as Vbws = 85 mph (38 m/s) corresponding to the ASCE and NESC basic wind speed for the route.

The wind velocity pressure qz shall be calculated by the NESC formula: qz = 0.00256 V^2 Kz GRF I Cf A in lb/sq ft.

Where:

- 0.00256 (0.613 metric) is the velocity pressure numerical coefficient reflecting the mass density of air for the standard atmosphere
- Kz is the velocity pressure exposure coefficient
- V is the basic wind speed = 3 second gust wind speed at 33 feet (10.06 m) above ground for open terrain, Exposure C; i.e. Vbws in mph (m/s)
- GRF is gust response factor
- I is the importance factor (I being equal to 1.00 for OCS)
- Cf is the force coefficient shape factor
- A is the projected wind area

Note: Kz, V and GRF are based on open terrain with scattered obstructions (Exposure Category C as defined by ASCE, and are used as the basis for the NESC extreme wind criteria). For very exposed areas, the wind velocity pressure shall be increased by the ASCE factor Kzt.

For OCS structural calculations, loads due to wind shall be multiplied by the load factors given in NESC Table 253-1.

21.5.4 Atmospheric Pollution

The OCS equipment shall be resistant to polluted atmospheres, such as may occur in highly industrialized areas, salt-laden marine atmospheres near the ocean, and persistent fog. In addition, the OCS equipment shall be resistant to the corrosive atmospheres that may be found in cut-and-cover structures and other tunnels. These conditions prohibit the use of weathering steel (ASTM A588) in poles and other structural elements and hardware.

21.5.5 Ambient Temperatures Range

General: In developing the settings for the auto-tensioning devices (balance weight anchor arrangements), the designer shall take into consideration the typical and extreme ambient temperatures, as shown on the Baseline Drawings.

21.5.6 Conductor Wire Temperature Range

General: Based on the initial analyses, the messenger and contact wires and the parallel feeder conductors are likely to reach a maximum operating temperature of 145˚F in above grade sections.

21.5.7 Conductor Tensioning

General: The mechanical tensions in the messenger and contact wires shall be maintained automatically throughout the temperature ranges specified above.

21.6 Overhead Contact Line Design

The OCS shall be of a proven design using assemblies with required design life that is capable of sustaining satisfactory current collection for train operations at 110 mph.

The OCS Designer shall ensure the proposed placement of OCS poles and/or supporting structures; and wayside equipment enclosures will not block existing access roads, passenger circulations on the platforms, and/or trackside equipment anywhere along the alignment. For the location of the Wayside Power Cubicles (WPC) the OCS Designer shall coordinate with the TPS designer.

Where the installation of the foundation and guy anchor impacts the CPUC GO 118 required walkways the Design Builder shall reconstruct the walkways by allocating on the design plans the widening of the ballast walkway as needed.

The OCS Designer shall design sufficient clearance between the feeder cables and static wire, and grade crossing gate arm to mitigate any clearance issues. Further field measurement for the actual grade crossing offset might be required.

The catenary system in-span hangers shall be of stranded, rope-lay stainless steel or copper alloy (bronze) material, configured to provide a flexible, non-rigid method of contact wire support from the messenger wire.

The OCS design shall provide conductor-stringing data for all wire tensioning modes for the full range of the nominal design temperatures. Where F.T. designs are used, suitable tension-adjustment tables or graphs shall be provided for erection of cables and wires at ambient temperatures other than the normal design condition.

Messenger-to-contact wire hanger lengths and in-span positions shall be tabulated for the standard span lengths, covering the full range of spans in 5-foot increments, including the maximum and minimum mainline spans and required variations for overlap, anchor and bridge or tunnel approach spans. Specifications shall require the contractor to calculate actual hanger lengths based on field measured as-built span lengths.

G.O. No. 95 requires that all overhead trolley contact conductors shall be so supported and arranged that the breaking of a single "suspension" or fastening will not allow the trolley conductor, or live span wire, or current carrying connections to come within 10 feet from the ground or from any platform accessible to the general public: "For Trolley Contact Conductors of More than 1,500 Volts: Where in urban districts and not on fenced rights– of–way, trolley contact conductors of more than 1,500 volts shall be so suspended that if the conductor is broken at a single point it cannot fall within 10 feet from the ground or from any platform accessible to the general public." This practically requires that all catenary construction meet that specification.

For areas accessible to the public the hanger spacing in the catenary construction shall be reduced so that a broken contact or messenger wire will be supported from the hanger, and not reach with 10' of ground or any platform.

Other important aspects of the design are the provision of adequate clearances or provision of protective barriers and screens, together with effective grounding and bonding of the electrical system and wayside metallic objects, which are required to minimize safety hazards. The recommended minimum clearances between energized parts and grounded parts are detailed in Section 21.14.8. The location of OCS equipment, including poles and downguys, shall be coordinated with clearances defined in the G.O. No. 26-D.

21.6.1 Design Data

The OCS system designer shall be cognizant of and shall incorporate into the OCS design the fundamental design data and performance instructions, as defined in these Design Criteria, which include the following:

- Service and operations information
- Infrastructure characteristics
- Vehicle characteristics
- Pantograph characteristics
- Traction power system design
- Environmental conditions
- External limitations on contact wire height, uplift, system height, and/or clearances
- Life expectancy and desired maintenance/renewal philosophy for all components, plus
- Allowable grooved contact wire wear
- Specification of EMC limitations

21.6.2 Geometry of the Overhead Contact Line

The OCS shall consist of a simple, auto-tensioned catenary system, using a bare hard-drawn copper messenger wire supporting a nominally level (no pre-sag), solid hard-drawn copper contact wire by means of copper alloy or stainless steel current carrying hangers.

In general, the catenary shall be supported by pole mounted cantilever frames which shall be designed to provide the required system height and to register the correct stagger of the wires relative to the track centerline. The messenger wire shall be positioned vertically (plumb) above the contact wire. Back-to-back cantilevers, supported on single poles centered between tracks, can be used for the main tracks, and also in station areas. An aerial Static Wire (ground wire), connected at regular intervals to the track via impedance bonds, shall be run alongside the catenary to interconnect each OCS support structure and bracket, such that all OCS non-live metallic supports are at the same ground (and track) reference potential.

The longitudinal ATF shall be supported near the top of the OCS poles, preferably on the track side, but may be positioned on the field side where the right-of-way width or overhead structure configuration shown on the OCS layout drawings dictates.

The aerial parallel ATF's, and the aerial static/ground wires which connect all OCS supporting structures, shall both be fixed termination bare ACSR (Aluminum Conductor Steel Reinforced) conductors, except where local site conditions (reduced clearances, etc.) dictate the need to use insulated cables for the ATF's.

The method of auto-tensioning the messenger wire and contact wire shall be by balance weight and pulley tensioning devices. The tensions shall be applied to the contact and messenger wires using a yoke plate and balance weights, tensioning devices and anchoring positions.

The designer shall evaluate overlap arrangements, but the initial analyses indicate that the overlaps should comprise a 3-span configuration. Maximum tension lengths from anchor to anchor shall not exceed 5,600 feet in open route sections and adjacent to traction power substations and switching stations.

At approximately mid-distance between auto-tension terminations, mid-point anchor arrangements shall be installed, such that the maximum half tension lengths do not exceed 2,800 feet in open route sections and at power supply stations and switching stations. The 2,800 ft is from fixed anchor or midpoint to the last in-running registration.

The maximum permissible span length between supports that are shown on the Standard Drawings shall be verified using appropriate computer software programs, which shall take into consideration the permissible working range of the pantograph and allowable lateral displacement of the contact wire under the designated operating conditions, including dynamic movement of the vehicle and pantograph.

At overlap locations where sectionalizing is not required, uninsulated mechanical overlaps shall be installed that will permit the pantographs to transition smoothly from one tension length to the next under power.

Wherever practicable, the OCS shall be free running under overhead bridges, i.e., no OCS or feeder support attachments under the structure. Existing bridge clearances, if any, shall be reviewed to determine whether free-running OCS arrangements can be accommodated, which is the goal.

The designer shall secure permits for attachments to any third party owned bridges or structures where it is determined that OCS support, registration or termination attachments will be required.

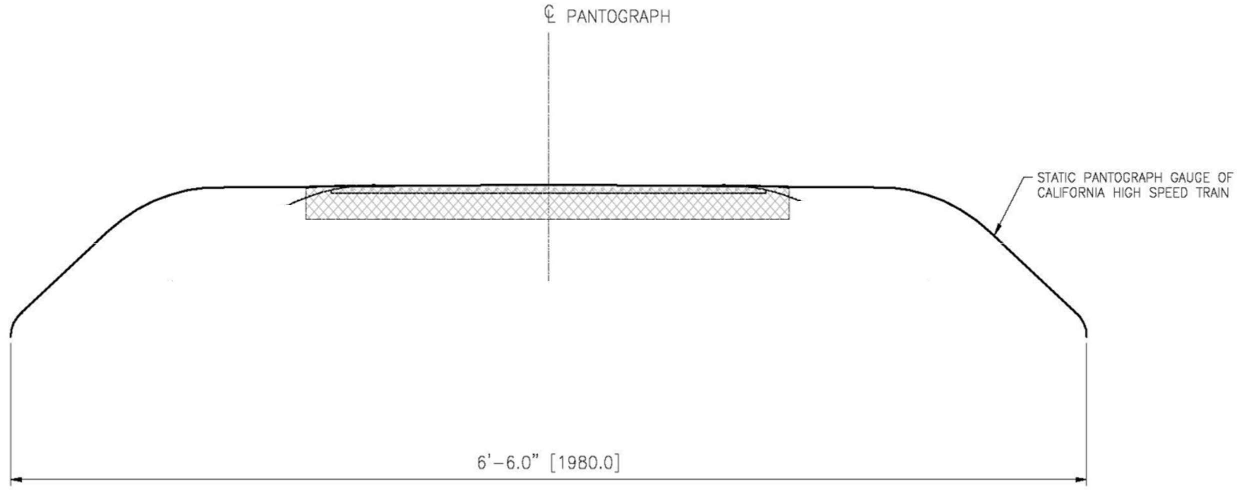
In tunnels, the OCS, feeders and static wires shall have been installed under a separate contract. The Contractor shall coordinate and design to match the Portal Interface locations.

In limited clearance locations, particularly at low headroom bridges, resilient arms, supporting and registering both messenger and contact wires, may have to be utilized. If any extremely restricted clearance locations are identified, it may be necessary to adopt the use of conductor rail arrangements.

21.6.3 Geometry of the Pantographs

The Overhead Contact Line shall be designed to accommodate pantographs with a pantograph head profile, as shown in Figure 21-1, which shall be based on the geometry detailed in EN 50367: 2006 Figure B.3, but having a pantograph head width of 78 inches (1980 mm), and with horns not made of insulating material.

Figure 21-1: Combined Pantograph - Maximum Static Geometry



Pantograph heads fitted with contact strips, having independent suspensions, shall remain compliant to the overall profile with a static contact force of 15.75 lbf (70 N) applied to the middle of the head.

21.6.4 Wire Heights and Gradients

The contact wire shall be installed and maintained at a nominal constant height of 22 feet at the supports, the maximum vehicle load gauge height will vary depending on the segment to be compatible with current and future Caltrain Vehicles and Freight traffic, and accommodate potential future CHSRA vehicles.

Exceptions shall be addressed on a site-specific basis, and subject to Caltrain's approval. The contact wire installation height at supports shall take into consideration the effect of wire sag, due either to temperature rise and installation tolerance (including track construction and maintenance tolerances).

For sections of the route where trains carrying "double-stack" loads are permitted to operate, the support height for the contact wire shall be set at 22' above mean top of rail (AMTOR) level. This shall be considered the normal contact wire height (CWH).

For restricted clearance sections of the route (such as at overpasses) in "double-stack" territory, the support height for the contact wire may be reduced to a minimum value of 21'- 3" AMTOR, provided short-span support arrangements supported from the structure are employed and subject to concurrence by Caltrain, and by the CPUC and the owner of the structure.

For restricted clearance sections of the route (such as in the San Francisco tunnels), where the trains are operating solely over dedicated ROW, the support height for the contact wire may be reduced to a minimum value of 17'- 0" AMTOR. The wire height might need to be increased to meet all plate clearance requirements of all tracks encompassed by this electrification project.

For unrestricted sections of the route north of Bayshore, where the trains are operating solely over dedicated ROW, the support height for the contact wire may be reduced to 19'- 0" AMTOR. This shall be considered the normal contact wire height (CWH) for dedicated Caltrain-only operation.

To assure continuity of current collection by a fully extended pantograph, the OCS design shall be checked to ensure that, under the most adverse operating condition, the contact wire height does not exceed 24′- 0″.

The maximum permissible contact wire gradients and the corresponding maximum gradient changes shall not exceed, according to the maximum speed, the following values:

Table 21-3: Maximum Permissible Contact Wire Gradient versus Operating Speed

Maximum Speed (mph)	Maximum Contact Wire Gradient	Maximum Contact Wire Gradient Change
125	2/1000	1/1000
100	3.3/1000	1.7/1000
75	4/1000	2/1000
60	6/1000	3/1000
45	8/1000	4/1000
30	13/1000	6.5/1000

On tangent track (straight track), the contact wire shall be staggered at each location to alternate sides of the pantograph center line, and the stagger shall normally be set at 9 inches.

On curved track, the staggers shall be calculated on a case by case basis taking into account the track superelevation, radius of curvature, and wind speed, but shall not exceed 9 inches.

Registration elements (steady arms, contact wire clips, etc.) shall be as light as possible to minimize the possibility of creating a hard spot in the contact wire.

21.6.5 Compliance of the Overhead Contact Line System with the Infrastructure Gauge

The OCS design shall comply with the static and dynamic envelopes, as defined in the Trackway Clearances Chapter, for vehicles which will run on the train tracks.

The dimensions of tunnels and other structures shall be mutually compatible with the geometry of OCS and the dynamic envelope of the pantograph, the static profile of which is shown in Figure 21-1.

21.6.6 Fabrication and Erection

The OCS designs and arrangements shall provide for ease of shop fabrication, on-site assembly, field erection, and construction. Catenary components and assemblies, such as cantilevers, steady arms, suspension devices, and related hardware shall be standardized. To the extent that is economically feasible, key dimensions, weights, mounting points, heights and interface tolerances shall be patterned to provide interchangeable, multi-use designs. The design of the equipment and component parts shall be suitable for pre-assembly and for subsequent assembly shipment. They shall afford final on-site assembly and field erection of the units with a minimum of preparation and equipment adjustment.

All components shall be specifically manufactured for use as electrical products and shall be designed to conform to the requirements set forth in these criteria. The engineering final design shall determine the exact material specification(s) and identify these requirements within each relevant specification section.

The current collector pantograph is a hinged frame that is spring loaded to maintain pressure under the contact wire and to accommodate variations in the vertical height of the contact wire. This pressure creates uplift of the contact wire and can result in movement of the messenger wire. At the higher operating speeds, aerodynamic forces can be exerted on the pantograph frame, which might result in further uplift of the contact and messenger wires. The design analysis shall identify values of uplift. Mechanical clearance from the pantograph to any fixed item, excluding the steady arm or registration pipe of the cantilever, shall be not less than 3 inches. Clearance to steady arms and registration pipes shall not be less than 1½ in.

Design loadings shall be fully considered in cantilever, bracket, and cross-span arrangements, as defined in the previous sections of these criteria. Cantilever frames with hinged brackets shall be used to minimize the application of torsional loading on the pole or structure, and to limit possible domino failure effects caused by a broken-wire condition.

The design shall require that all OCS cable, wire, strand, rod, and other equipment, produced in ferrous, non-ferrous, and related materials, shall be manufactured in accordance with the applicable ASTM or other referenced industry standards. The manufacturing methods and materials shall be proven for use on, and compatible with, an electrified catenary system.

Typically, all catenary assemblies, components, hardware and related equipment shall be designed in such a manner that they will allow an experienced and proven OCS manufacturer or supplier to furnish the equipment from their standard product range. All OCS designs shall be subject to Shop Drawing submittals and review by Caltrain.

21.6.7 Overlap, Turnouts and Crossovers

The overlaps in the OCS shall provide for a mechanically smooth passage of the pantograph. Uninsulated overlaps shall be equipped with full electrical continuity jumpers. Insulated overlaps shall be used to the greatest extent practicable for sectionalizing purposes. Turnouts and crossovers shall be fitted with the same style of OCS as the mainline A.T. system. Section insulators can be used at turnouts. For multi-track applications, the preferred support arrangement is the portal, but headspan structures may be employed where special conditions warrant their application.

21.7 Conductor Tensions

The permissible tensile loading of the wires and ropes to be used shall consider the weighted parameters, as indicated in EN 50119: 2001, clauses 5.2.4, 5.2.5, and 5.2.6, which include maximum working temperature (excluding short circuit loading), allowable wear, wind loads, tensioning accuracy and efficiency, termination fitting effects, welded or soldered joint effects, and creep, as applicable. In addition, the current heating effects of short circuit faults, occurring during peak operations shall be assessed to ensure that the maximum permissible conductor temperatures are unlikely to be exceeded.

21.8 Catenary Conductors

Analyses have shown that the following conductors form a viable catenary, and these conductors are indicated on the Standard Drawings. The same conductor and cable types and sizes shall be used throughout the entire system.

21.8.1 Contact Wire

The contact wire is a grooved hard-drawn copper wire, of the requirements shown on the Standard Drawings regarding the material designation and composition, conductor appearance and condition, clamping groove, electrical characteristics (resistivity, resistance per mile (km)), tensile strength and percentage elongation after fracture, breaking load, and mass of the wire.

21.8.2 Messenger Wire

The messenger wire is stranded Bronze, wire of the requirements shown on the Standard Drawings regarding the material designation and composition, conductor appearance and condition, tensile strength and percentage elongation after fracture, breaking load, and mass of the wire.

21.8.3 Hanger Wire

The suitable flexible conductor for the hanger wire as shown on the Standard Drawings which, together with the messenger wire and contact wire clips, shall provide an electrical connection between the messenger and contact wires.

21.8.4 Alternate Conductors

No alternate conductors will be allowed.

21.9 Other Overhead Conductors and Cables

Insulated cables and conductors required by other disciplines, such as signal cable, signal-power cables, control wires and communications cables, will generally be installed underground but may, on occasion, have to be mounted aerially on the OCS poles.

21.9.1 Aerial Conductors

These aerial conductors shall be mounted and spaced on the OCS support structures in accordance with the more stringent requirements of the CPUC General Order No. 95 rules, as they apply to each system classification. Mounting arrangements shall provide for the safety of maintenance personnel.

These cables and conductors shall be mounted and profiled in such a manner as to avoid the Overhead Contact Line Zone and Pantograph Zone (Figure 21-5) to the greatest extent practicable.

Loading calculations and structural designs for the support of these cables and conductors shall comply with these design criteria.

21.9.2 Other Insulated cables and bare conductors

Insulated cables and bare conductors, other than the catenary conductors identified above, that are associated with the OCS may parallel or cross Caltrain’s right-of-way, including the parallel ATF’s, and static (ground) wires.

Parallel ATF

In general, the parallel ATF shall be a bare stranded ACSR conductor for use throughout the system, as shown on the Standard Drawings. Since the mainline will generally be two-track, with platform tracks at intermediate stations, two ATF's are to be installed; one on each side of Caltrain's right-of-way. At locations where a bare conductor cannot be installed, appropriately sized insulated 25 kV cables, as shown on the Standard Drawings, with appropriate sealing ends, shall be substituted and spliced into the bare conductor, which may or may not have to be terminated on a dead-end anchor pole.

Static (Ground) Wire

In general, the static wire shall be a bare stranded ACSR for use throughout the system, as shown on the Standard Drawings. Two static wires are to be installed - one on each side of Caltrain's right-of-way – interconnecting all metallic OCS support structures, including OCS poles and bridge drop pipes and wall brackets, to provide a continuous ground connection.

Shunt Wire

At utility crossings, the electrification design shall include the installation of a Shunt Wire, which shall be ACSR, as shown on the Standard Drawings, to shunt the utility crossing span to ground to protect the safety of the public and rail or utility workers in case the utility conductors in the crossing span fail. The Shunt Wire installed above the feeder wire, must be consistent with the GO 95 strength requirements for a 50 kV system (GO 95 Section IV).

Insulated 25 kV Cable

Power feeder cables, where used, shall be insulated with a black, low-smoke, flame-retardant, ozone-resistant, ethylene-propylene compound jacket and the aluminum conductor shall be covered with a double-wrapped separator tape or extruded semi-conducting Ethylene propylene rubber (EPR) screen, as shown on the Standard Drawings.

Return cables, where used, shall be insulated with a black, low-smoke, flame-retardant, ozone-resistant, ethylene-propylene compound jacket and the conductor shall be coated, soft-drawn stranded copper, covered with a double-wrapped separator tape or extruded semi-conducting, EPR screen, as shown on the Standard Drawings.

21.10 Dynamic Behavior and Quality of Current Collection

Good quality interactive dynamic performance with minimum wear can be assured by consideration of the quality of current collection, which has a fundamental impact on the life of the contact wire and pantograph components. Compliance with several measurable parameters, as detailed below, shall be achieved.

21.10.1 Requirements

The number of pantographs in service per train is limited to one per trainset. This allows the Phase Breaks to be of a short length. The Phase break will have at a minimum a 17' neutral section, with the neutral section grounded.

21.10.2 Contact Wire Uplift or Vertical Movement of the Contact Point

The contact point is the point of mechanical contact between the pantograph contact strip and the contact wire.

The vertical height of the contact point above the track shall be as uniform as possible along the span length; this is essential for high-quality current collection. The maximum difference between the highest and the lowest dynamic contact point height within one span shall be less than 3 inches at the maximum operating speed of 110 mph.

In order to maximize safety under all operating conditions (including strong wind conditions and slight mis-adjustments of the pantographs), the dynamic pantograph envelope at the maximum operating speed shall consider twice the value of the estimated or simulated uplift at the support point.

The design of the OCS cantilever and registration shall allow the uplifted steady arm to clear the dynamic pantograph envelope. For initial design purposes, a total minimum uplift of 10 inches shall be assumed.

21.10.3 Collection Quality.

To check the performance capability of the current collection system, the following data, as a minimum, shall be measured:

- The contact force;
- The contact wire uplift at the support as the pantograph passes;
- The percentage of arcing and duration of arcs longer than 5 ms.

In addition to the measured values, the operating conditions (train speed, location, etc.) shall be recorded continuously, and the environmental conditions (rain, temperature, wind, tunnel, etc.) and details of the test configuration (parameters and arrangement of pantographs, type of OCS, etc.) during the measurement tests shall be recorded in the test report.

In order to maintain the contact wire on the pantograph head, the design factors to be considered shall include OCS conductor blow-off, contact wire height, contact wire stagger, contact wire midspan offset, contact wire stagger effect on tangent, contact wire deviation due to movement of hinged cantilevers, mast deflection due to imposed operational loads, vehicle roll and lateral displacement, width and sway of pantograph, track tolerances, OCS erection tolerances, pantograph shape effect, and a pantograph security factor.

The design shall consider the effects of environment, track geometry, track maintenance clearance tolerances, vehicle and pantograph sway, and installation and maintenance tolerances. Vehicle roll into the wind shall be taken equal to be 50% of the maximum dynamic roll value, in accordance with the AREMA Manual for Railway Engineering.

21.11 Current Capacity of Overhead Contact System

The OCS, including parallel feeders, return circuit conductors and feeder connections, shall be designed to cater to the electrical current loading under steady state peak period operating and fault conditions, as defined by the system design, under the environmental and climatic conditions defined in Section 21.5.

In addition, the current heating effects of short circuit faults and durations, resulting from automated circuit breaker closure sequences (if adopted), which occur during peak operations shall be assessed.

The maximum temperature rise in the conductors, caused by the load currents, shall not lead to conductor temperatures at which the mechanical properties are impaired. The maximum permissible temperatures for bare conductors are given in the following table:

Table 21-4: Maximum Permissible Bare Conductor Temperatures

Conductor Material	Max. Temperature (°F)	Max. Temperature (°C)
Normal and high strength, high conductivity Copper	176°F	80°C
Silver Copper alloys	212°F	100°C
Cadmium Copper alloys	176°F	80°C
ACSR	212°F	100°C

The melting point of any grease used in the strands of the conductors shall be higher than the temperature limits specified above.

21.12 Sectionalizing and Switching

The OCS and related traction power distribution system shall be sectionalized in accordance with Caltrain's operating requirements and shall facilitate and support revenue operations of the Caltrain system. An arrangement providing continuity and flexibility in operation of the system during contingency modes of operation shall be incorporated. In addition to sectionalizing at the traction power facilities, the OCS shall be sectionalized at crossovers or other special trackwork (i.e., turnouts) locations, and in the yard, to provide for OCS section isolation and operation around out-of-service tracks.

To allow bi-directional running, enabling trains to continue operation under emergency conditions and to facilitate routine OCS maintenance, the OCS shall be divided into electrical sections and sub-sections. On the main tracks, only phase breaks (utilizing high speed section insulators) and insulated overlaps shall be used for power supply sectionalizing purposes. Mechanical section insulators will not be permitted except when used in the OCS above slow speed track turnouts and in the yard and shop areas.

To form the insulated overlaps, insulation shall be cut into the out-of-running sections of the messenger wire and contact wires of the two overlapping catenaries, having between them a limited air gap electrical clearance. The insulated overlap thus provides a sectionalizing point in the OCS as required for operational and maintenance reasons, but allows pantographs to transition smoothly from one energized electrical sub-section to the next under power.

The design of section breaks shall utilize an insulated air-break or insulated overlap. At double-track locations, the air-break/overlap shall be applied to both tracks.

The overall length of the short neutral section design shall be less than the shortest distance between pantographs. The short phase break is preferred due to the limited space between station platform and the phase break location. The long phase break shall not be precluded once the maximum pantograph spacing information is available.

If the long neutral section design with two insulated overlaps or air-breaks is implemented as the phase break, the length of the neutral zone between the two insulated overlaps or air-breaks shall be larger than the maximum distance between pantographs.

Jumper cables shall maintain electrical continuity at special trackwork locations where it is necessary to have a physical separation in the OCS. At locations where jumper cables are used to provide full-feeding electrical continuity, they shall equal the electrical capacity of the OCS circuit.

21.12.1 Pantograph Spacing for Design of the Overhead Contact Line

The overhead contact line design shall be based on rolling stock operating only one raised pantograph.

Phase Breaks

The design of the OCS phase breaks shall permit approved trains to move at all speeds up to the designated maximum operating speeds from one electrical section to an adjacent electrical section without bridging between two electrical phases or two separate utility supply systems.

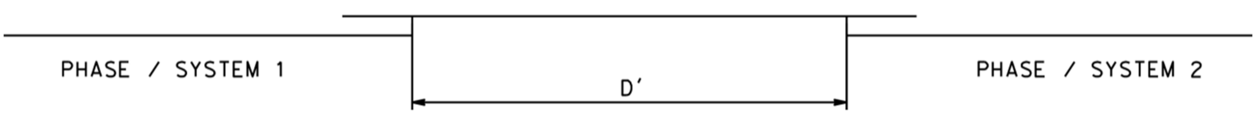
Trains shall traverse the entire phase break with pantographs raised and in contact with overhead contact wire, but with the pantograph breakers open.

The neutral section shall be configured such that it can be connected to, and energized from, either of the adjacent electrical sections by remotely controlled disconnect switches with the provision of appropriate interlocks to ensure the different phases cannot be inter-connected under any circumstances.

The geometry of the phase break elements shall prevent pantographs short-circuiting or bridging between power systems. Provision shall be made in the rolling stock design to avoid bridging of adjacent power supply systems should opening of the onboard circuit breaker(s) fail.

For any Caltrain Electrification Project, the Short Phase Break (Figure 21-2) will be used.
The length of the neutral section shall be at least 17’ feet.

Figure 21-2: The Short Phase Break



Conditions: D’ > 17 ft

21.12.2 OCS Sectionalizing

The disconnect switches shall be motorized and shall be both remotely and locally controlled fixed installations.

Switch indication panels shall be provided at or adjacent to each switching location, indicating the status of each switch and whether the OCS is energized / de-energized / grounded.

Procedures and responsibilities for de-energizing and grounding the OCS along with the duties and responsibilities of the Power Dispatcher and maintenance personnel shall be defined in the emergency plan.

Disconnect Switches

To facilitate maintenance work and emergency operations, the OCS shall be equipped with disconnect switches at all primary feeding and by-pass feeding locations. Where feasible, the OCS disconnect switches shall be pole-mounted at trackside and shall be single pole motorized switches capable of remote operation and also of local motorized or manual operation.

The switches shall provide for isolation of discrete sections of the OCS (track), such that segments of the OCS can be de-energized for maintenance purposes. The disconnect switches shall also provide for by-pass feeding arrangements that can be implemented during emergency conditions to permit contingency modes of operation.

Remote operations shall be performed from the Operations Control Center (OCC) and shall be accomplished using the SCADA system. All disconnect switches shall be of the (non) load-break type and shall be rated for the system voltage and anticipated current loads, and be designed to carry worst-case overload and short circuit currents without overheating.

As a safety precaution, the switch operating mechanism shall be fitted with a locking bar that will permit the attachment of maintainer locks. In general, the disconnect switches shall be of the two-position type, providing for Closed (inter-connection between adjacent electrical sections), or Open (no electrical inter-connection).

For locations where solid grounding of the OCS is required, the OCS disconnect switches shall be of the three-position type, providing for Closed, Open, and Closed to Ground connections.

Where motorized disconnect switches are located in the vicinity of a traction power facility, the 125 VDC motor power shall be supplied from that facility. At remote locations, such as interlockings, the 125 VDC motor power shall be supplied from a wayside power cubicle (WPC).

While the disconnect switches are within the OCS Designers responsibility, the wayside power facilities supporting them are covered under the Traction Power Facilities Chapter.

Surge Arresters

Over-voltage protection of the OCS shall be provided by means of surge arresters, which shall be rated to withstand the maximum system voltage and anticipated voltages from any paralleling high voltage transmission lines. A sufficient number of arresters shall be installed to discharge the energy resulting from lightning strikes without failure of the units. As a minimum, the design shall require arresters to be installed at feeder disconnect switches and at all traction power facilities to assure protection of the feeder cables and upstream equipment. In addition, arresters shall be provided at points of reduced clearance, such as restricted clearance overhead bridges and tunnel portals.

21.13 Insulation Coordination Requirements for OCS Installations

Insulation coordination implies selection of the electrical insulation characteristic of the equipment with regard to its application and in relation to its surroundings. Insulation coordination can only be achieved if the design of the equipment is based on the stresses to which it is likely to be subjected during its anticipated lifetime.

The OCS shall be designed with insulated catenary support arrangements. All insulating components shall be electrically rated to withstand a nominal voltage of 25.0 kV, and a maximum operating voltage of 29 kV, and shall have a Basic Insulation Level (BIL) of 250 kV. The flashover rating shall conform to the minimum requirements as indicated in CPUC G.O. 95. The insulator shall also have an impulse voltage withstand level of 250 kV. Insulator units and devices shall also be capable of power-frequency withstand voltage, wet of no less than 125 kV AC without surface flashover or damage, and shall be capable of operating with these types of occurrences on a regular basis.

All insulating assemblies and components shall be designed to safely carry the mechanical and electrical loads to which they shall be subjected. Insulation properties and methods of manufacture shall conform to all applicable ANSI, ASTM and related industry standards.

Pollution categories and associated creepage distances are also covered in EN 50124-1, and insulation for the system shall be designed accordingly.

21.14 OCS Clearances and Protection against Electric Shock

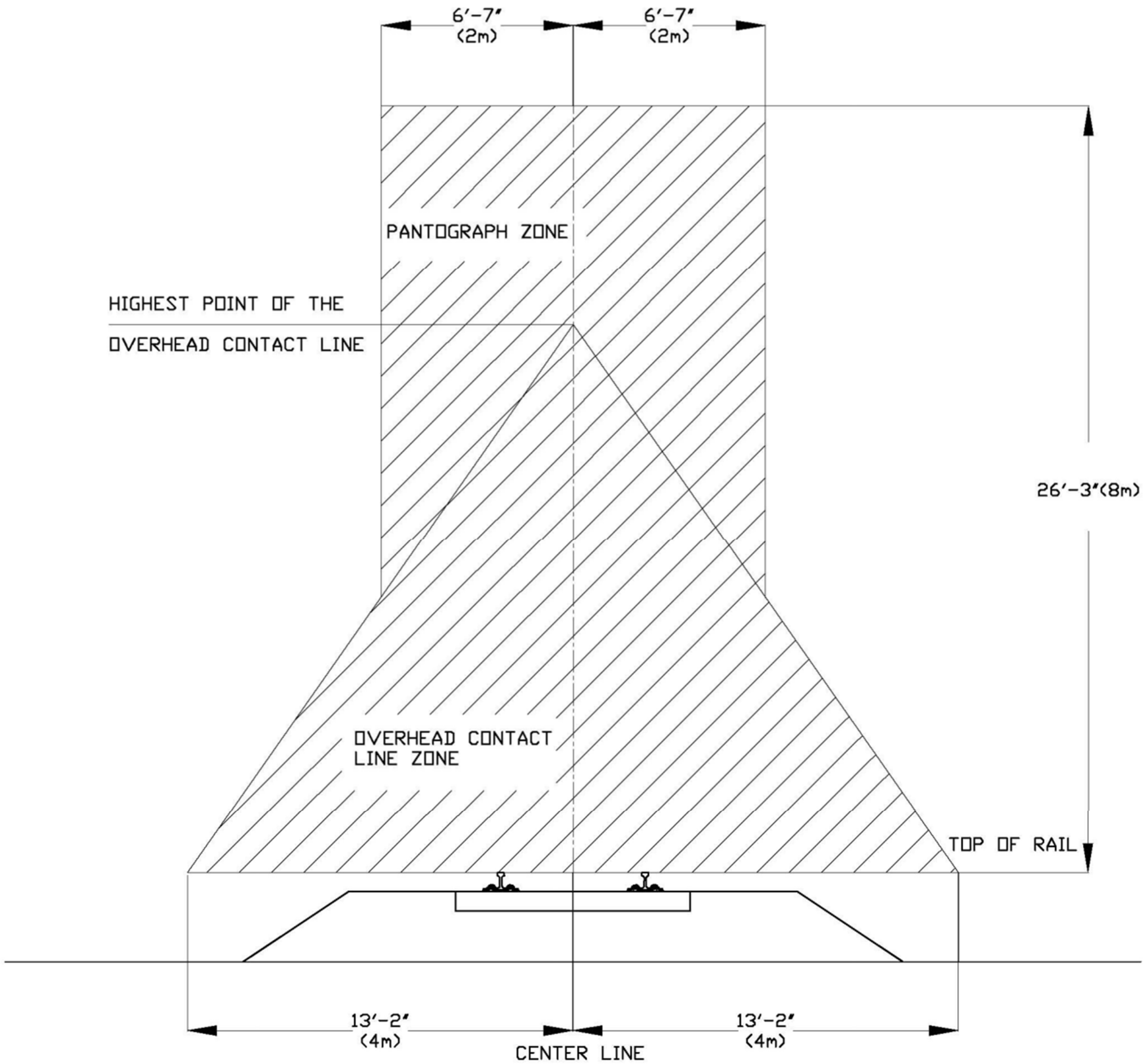
Protection against electric shock can be achieved by establishing adequate safety clearances that minimize the possibility of direct contact by persons with energized parts, and/or by erecting suitable barriers or screens to prevent direct contact, and installing appropriate signs warning of the potential dangers.

21.14.1 Overhead Contact Line Zone and Pantograph Zone

Structures and equipment may accidentally come into contact with a live broken contact line, or with the live parts of a broken or de-wired pantograph or energized fragments. Figure 21-3 has been derived from EN 50122-1: 1998 Figure 1 and defines the zone inside which such contact is considered probable but which limits are unlikely to be exceeded by a broken overhead contact line or damaged energized pantograph, or energized fragments thereof.

Note: The damaged pantograph may be live, even though it is not in contact with the overhead line, because it is inter-connected with other energized pantographs or because the train is in regenerative braking mode.
The limits of the overhead contact line zone below top of rail extend vertically down to the earth surface, except where the tracks are located on an aerial structure where they extend down to the deck of the aerial structure. In the case of out of running OCS conductors, the overhead contact line zone shall be extended accordingly.

Figure 21-3: Overhead Contact Line Zone and Pantograph Zone



Source: Derived from EN 50122-1: 1998 Figure 1

21.14.2 Protection by Clearances from Standing Surfaces

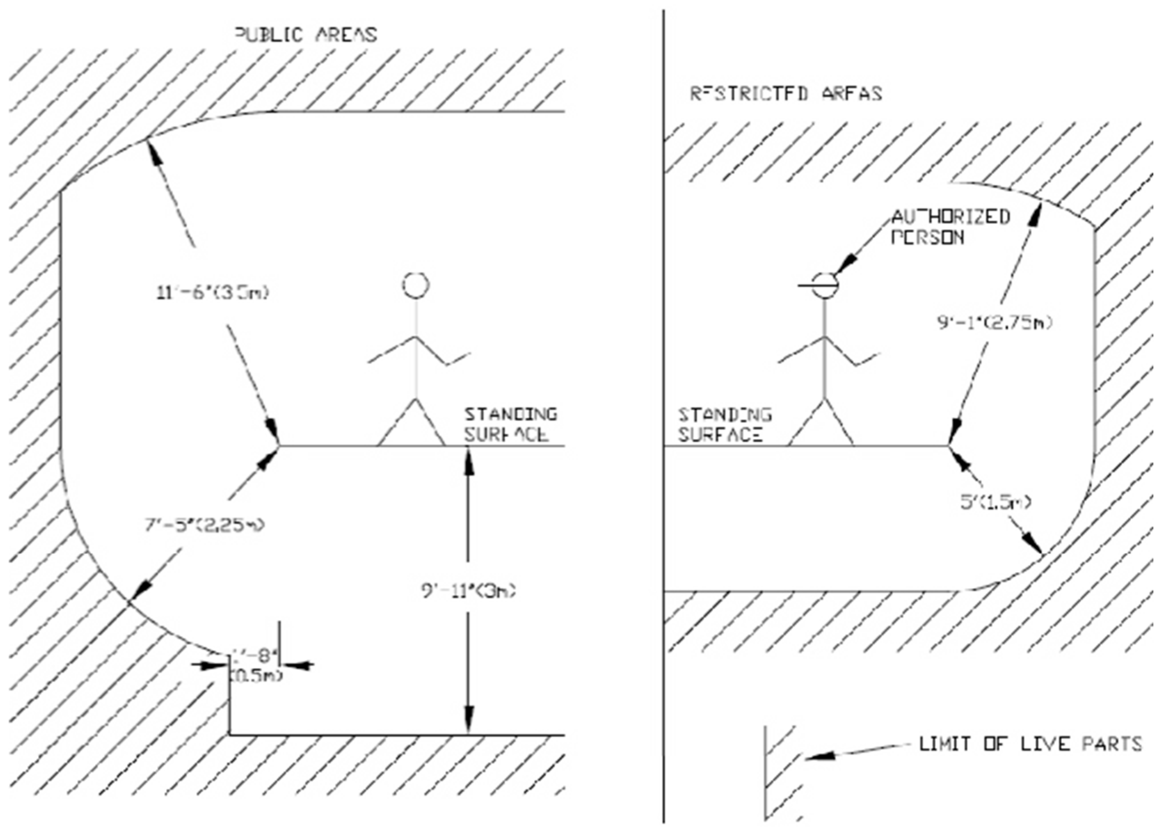
The minimum unconstrained clearances from energized parts to generally accessible areas (no barriers, screens or other physical restrictions to movement) for 25 kV systems have been derived from EN 50122-1: 1998 Figure 14 and values are depicted in Figure 21-4 for both public areas and restricted areas. The values shown are based on touching in a straight line without the use of tools or other objects and shall be achieved under all climatic and loading conditions.

These requirements apply to clearances from standing surfaces used by people to accessible live parts on the outside of vehicles as well as to live parts of the OCS.

Placing energized parts over walkways shall be avoided wherever practical.

Safe working clearances and approach distances for qualified employees shall be developed by the applicable Agency for inclusion in the Safety Manual and appropriate work practices and procedures documents.

Figure 21-4: Minimum Required Safety Clearances – Unconstrained Access



21.14.3 Protective Screening and Barriers for Standing Surfaces in Public Areas

The requirements for protective screening and barriers for use in public areas for protection against direct contact with adjacent live parts on the outside of vehicles or adjacent live parts of an overhead contact line system for normal voltages up to 25 kV AC to ground, where clearances are less than those shown in Figure 21-4, have been derived from EN 50122-1: 1998 Figure 18 and are shown in Figure 21-7 and are summarized as follows:

Where the energized parts are located below the standing surface, protection of the standing surface shall be by means of a solid barrier.

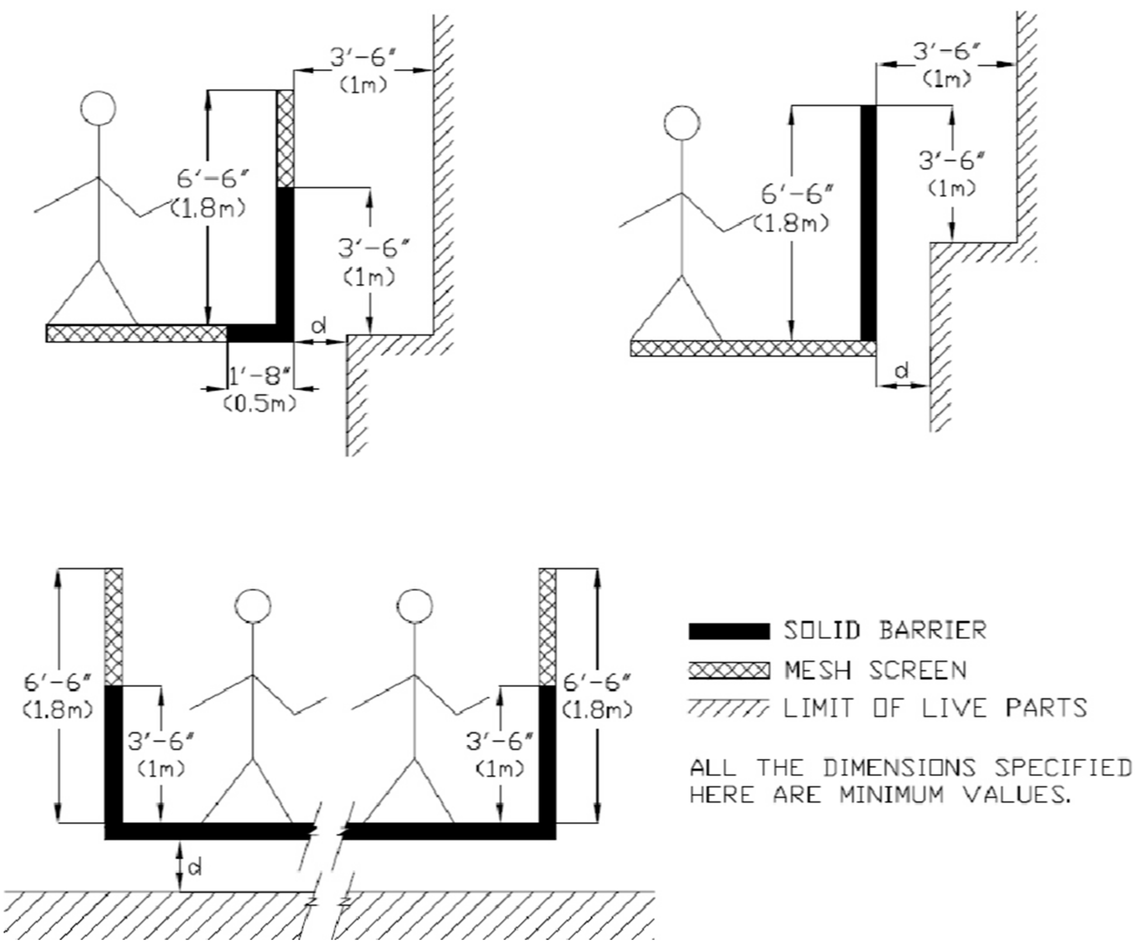
The minimum height of the protective barrier – solid barrier or a combination of solid barrier plus mesh screen, as shown - shall be 6′- 6″.

For Caltrain Electrification Projects protective barriers of greater height are required. The minimum height of the protective barrier for any Caltrain Project shall be 9'-6", with the top 3'-0" being a curved shape where pedestrians are expected. Where pedestrians are not expected the top 3'-0" shall be straight.

The value of Dimension "d" between the protective screen or barrier and live parts shall be determined from Table 21-5. Where mesh screens are used, 4 inches shall be added to the value of Dimension "d" and where buckling or warping of solid barriers is likely, 1.25 inches shall be added, in accordance with EN 50122-1 Clause 5.1.3.1.2.

The length of the protective screening and/or barrier on structures that cross over the electrified railroad, which protect publicly accessible standing surfaces, shall be extended laterally beyond and normal to the live parts of the overhead contact line by at least 10 feet (3.05 m) on each side. In the case of energized conductors not being used for current collection (e.g., line feeders, reinforcing feeders, out of running overhead contact lines), the barrier shall extend for a width of at least 10 feet (3.05 m) on each side of the conductor, with the provision that movements due to dynamic and thermal effects shall be taken into account.

Figure 21-5: Clearances from Protective Screens and Barriers for Standing Surfaces in Public Areas



Source: Derived from EN 50122-1: 1998 Figure 18

21.14.4 Protective Screening and Barriers for Standing Surfaces in Restricted Areas

The requirements for clearances from protective screening and barriers for standing surfaces in restricted areas for protection against direct contact with adjacent live parts on the outside of vehicles or adjacent live parts of an overhead contact line system for normal voltages up to 25 kV AC to ground, where clearances are less than those shown in Figure 21-6, have been derived from EN 50122-1: 1998 Figure 16 and 17, and are shown in Figure 21-8 and are summarized as follows:

For standing surfaces above live parts on the outside of vehicles or above live parts of an overhead contact line system, the protection shall be of solid barrier construction.

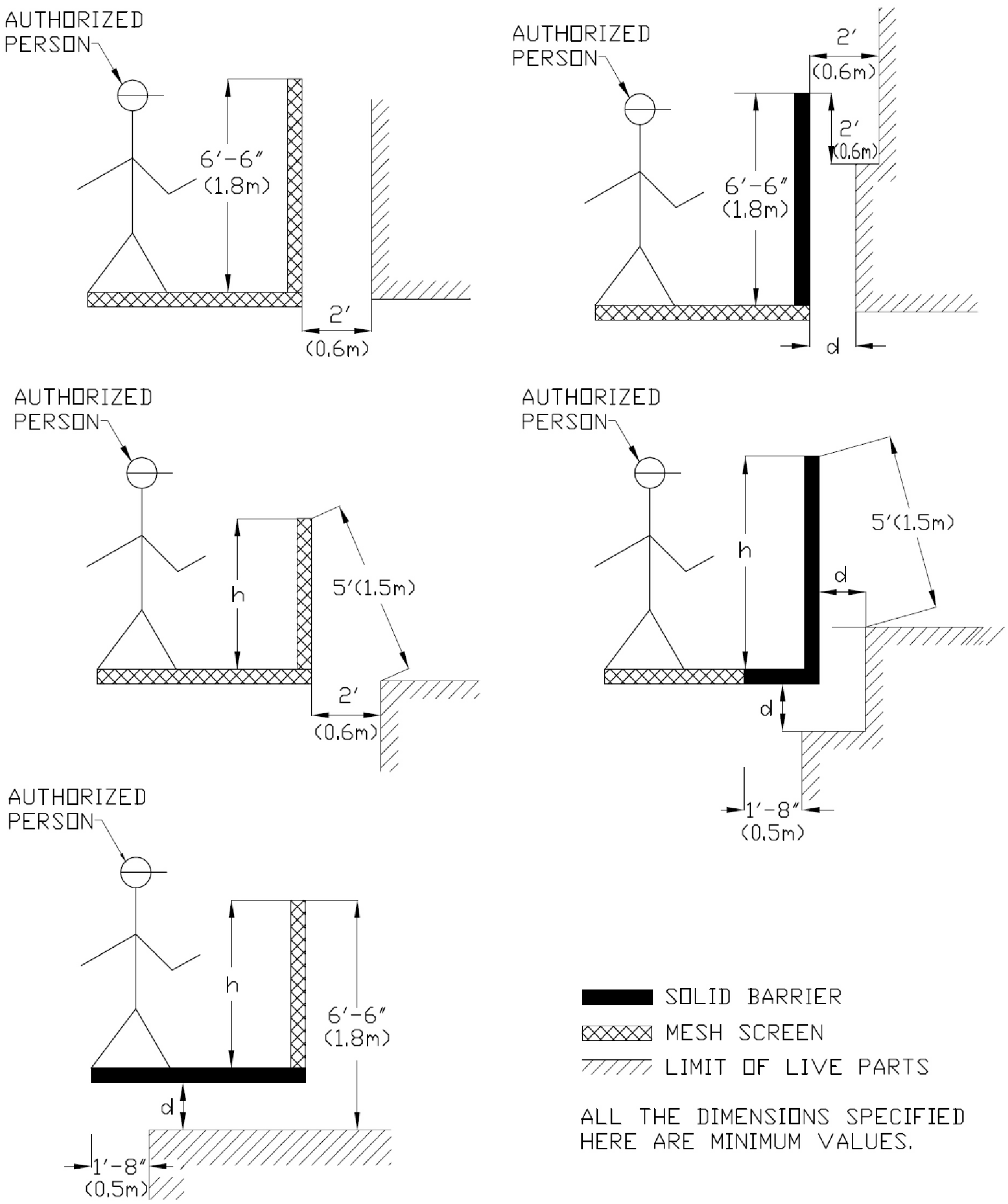
The length of the solid barrier, protecting the standing surface, shall correspond to the pantograph zone and shall extend beyond the live parts of an overhead contact line by at least 1 foot 8 inches. In the case of energized conductors not being used for current collection (e.g., line feeders, reinforcing feeders, out of running overhead contact lines), the barrier shall extend for a width of at least 1 foot 8 inches on each side of the conductor, with the proviso that movements due to dynamic and thermal effects shall be taken into account.

The height "h" of the protective screening and barrier shall be such that a clearance of 5 feet from the top of the protective screening and barrier shall be maintained (see Figure 21-6).

The height of the side protective screenings and barriers shall correspond to the height of the required safety railing but should be a minimum of 3 feet 6 inches.

The value of Dimension "d" between the protective screen or barrier and live parts shall be determined from Table 21-5. Where mesh screens are used, 4 inches shall be added to the value of Dimension "d" and where buckling or warping of solid barriers is likely, 1.25 inches shall be added, in accordance with EN 50122-1: 1998 Clause 5.1.3.1.2.

Figure 21-6: Clearances from Protective Screenings and Barriers for Standing Surfaces in Restricted Areas



Source: EN 50122-1 Figure 16 and 17

21.14.5 Additional Requirements for Protection Barriers and Screens

Protection barriers or screens shall be of sufficient strength and shall be supported rigidly and securely enough to prevent them from being displaced or dangerously deflected by a person slipping or falling against them.

Barriers and screens shall be permanently fixed and shall be removable only with tools.

Barriers in public areas shall employ non-removable, captive fasteners.

Barriers shall be of solid construction and fabricated from either conductive or non-conductive materials.

Non-conductive barriers shall be surrounded by a grounded, bare conductor that is inter-connected with the traction system ground, preferably at not less than two locations.

Conductive barriers shall be bonded and grounded by inter-connection with the traction system ground, preferably at not less than two locations.

Screens shall be of grounded, conductive, open mesh materials, and shall be grounded by inter-connection with the traction system ground, preferably at not less than two locations. Non-conductive mesh or plastic-coated metal mesh shall NOT be used.

Conductive mesh screens shall be constructed such that a cylinder, greater than ½ inch (13 mm) in diameter, cannot be pushed through the mesh. Mesh screen construction shall be such that required clearances to energized parts are maintained.

The style of barrier to be employed is dependent upon type of standing surface and its proximity to the energized parts, and whether the surface provides for public or restricted access, as detailed above.

The size of the barrier or screen shall be such that energized parts cannot be touched in a straight line by persons on a standing surface.

The design of the protective screens and barriers shall minimize the loading on the existing structures and the adverse visual impact.

The metallic parts of overhead bridge screens and barriers shall be bonded to the static wires. Other metallic items under overhead bridges, within a lateral distance of 10 feet (3.05 m) of any energized and uninsulated equipment below the structure, shall be directly or indirectly bonded to the static wires.

21.14.6 Protection Against Climbing

Where there is public access or trespass is likely, anti-climbing protection shall be provided at buildings and other structures supporting energized parts of the OCS. The anti-climbing protection shall include signs warning of the dangers of high voltage.

Access to fixed ladders, particularly at signal poles and signal gantries, and the means of access to any roof or other place, which could allow non-authorized persons to approach energized parts, shall be secured or otherwise protected.

21.14.7 Clearances for Utility Lines Crossing over the Electrified Railroad

The minimum clearance for overhead power, communications or other utility lines, which are not part of the Traction Electrification System (TES), shall be in accordance with CPUC General Order No. 95 Rule 38 Table 2 and shall be measured from the highest energized point on the TES.

For any crossing of the high-speed lines, the utility shall comply with the requirements of CPUC General Order No. 95 with regard to the conductor suspension arrangements and strength of the structures immediately adjacent to the crossing point.

21.14.8 Electrical Clearances to Rail Vehicles and Structures

Clearances are classified as either Static or Passing.

Static Clearance is the physical air clearance between energized parts of a vehicle or OCS when not subjected to dynamic conditions or climatic influences or pantograph pressure, and an adjacent fixed structure or the grounded parts of a vehicle, while the vehicle is stationary.

Passing (or Dynamic) Clearance occurs under dynamic operating conditions that exist during the passage of a train, or when the OCS is affected by extreme climatic conditions, such as wind and/or ice loading. Passing (or Dynamic) Clearance is the physical air clearance between energized parts of either the vehicle or OCS and the grounded vehicle, or between energized parts of either the vehicle or OCS and an adjacent fixed structure.

Electrical clearances, shown in Table 21-5 and depicted in Figure 21-9, from energized parts to grounded parts of rail vehicles or structures are categorized as Normal and Minimum and are applicable, as noted, in Non-Polluted and Polluted atmospheric locations. Typical polluted conditions are detailed in Section 21.5.4 and the designer shall determine their applicability.

Polluted locations/areas shall be so noted in the designs, so all users are aware that increased clearances must be employed and maintained.

Table 21-5: 25 kV AC Electrical Clearances

Atmospheric Condition	Normal Clearance		Minimum Clearance	
	Static (CA)	Passing/ Dynamic (PA)	Static (CA)	Passing/ Dynamic (PA)
Non-Polluted	10.5 inches (270 mm) *	8 inches (205 mm) *	8 inches (205 mm) *	6 inches (155 mm) *
Polluted	12.5 inches (320 mm) **	10 inches (255 mm) **	10 inches (255 mm) **	8 inches (205 mm) **

* These clearance values are as stated in AREMA Table 33-2-2 (2014)
** For polluted atmospheres, 2 inches has been added as stated in AREMA Table 33-2-2 (2014)

The designated normal clearances shall be adopted at all locations, wherever practicable. Where it can be demonstrated that it is not practicable to provide normal clearances, adoption of the minimum clearances shall be permissible. However, prior to their adoption, the following factors shall be further evaluated:

- Fault current resulting from a breakdown of the electrical clearance.
- Vulnerability of the OCS and railroad infrastructure to damage should a breakdown of the electrical clearance occur.
- Consequences for the safety of persons should a breakdown of the electrical clearance occur.
- Application and maintenance of tolerances of the OCS and railroad infrastructure
- Economic and technical considerations.

The minimum clearance from bare energized ancillary conductors (the 25 kV ATF feeders) to grounded structures under worst case conditions in non-polluted areas is specified in the AREMA Manual Chapter 33 Table 33-2-2 to be 10.5 inches and 12.5 inches in polluted locations.

In a 2x25 kV AC system, there is a 180˚ phase difference between parts common to the energized ATF and parts common to the energized catenary system. The minimum clearance between these elements shall be as stipulated in Table 3 of EN 50119: 2009, which is 21.5 inches under static conditions or 12 inches under worst case dynamic conditions.

Enhanced clearances or other protective measures shall be provided at locations where there is a high probability of incidents due to birds, animals, icicles or vandalism, or for particularly vulnerable structures. The maximum practicable value of electrical clearance shall be provided at all locations.

21.14.9 Clearance Envelope at Fixed Structures

In determining the minimum vertical clearance envelope at fixed structures, including OCS support structures and signal bridges, the following factors shall be assessed, as shown in Figure 21-7.

The static vehicle outline, which shall be based on the size of the freight, Caltrain and high-speed rail vehicles as shown in Trackway Clearance Chapter.

The dynamic vehicle outline, which shall take into consideration the dynamic swept envelope, track position and maintenance tolerances, including railhead side wear, and the effects of vertical and horizontal curvature, including track super-elevation. Refer to the Trackway Clearances Chapter for further information regarding vehicle clearance requirements.

The position of energized parts on the rail vehicles, including the dynamic pantograph envelope, allowing for pantograph carbon wear and dynamic movements and deflections of the pantograph frame, and vehicle construction and maintenance tolerances. The pantograph envelope shall include an allowance for chording effects, if the pantograph is offset longitudinally on the vehicle from a truck centerline.

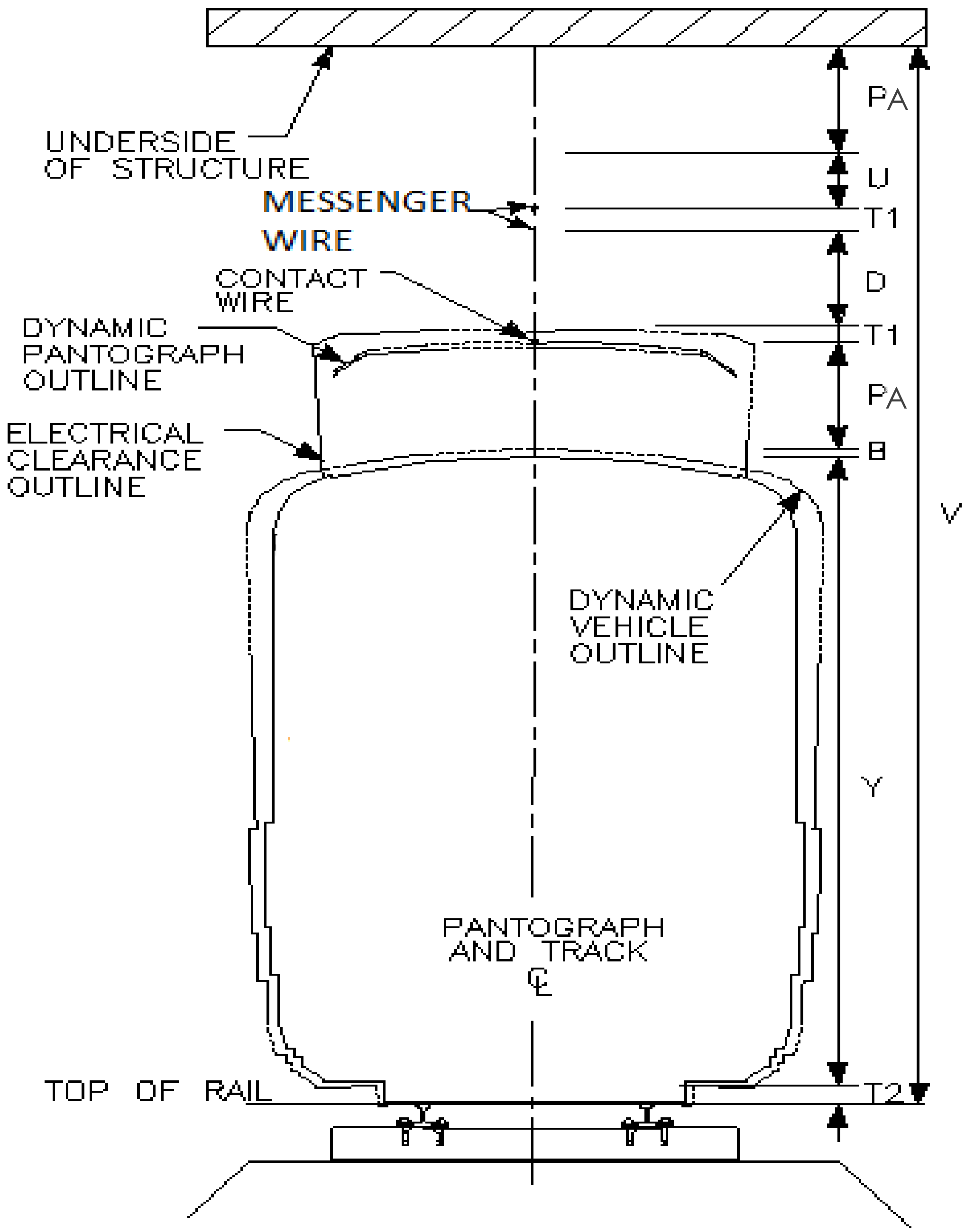
The position and size of energized parts of the OCS allowing for installation and maintenance tolerances, uplift and other dynamic movements, including those due to wind, temperature and loading conditions.

21.14.10 Electrical clearance values as applicable for non-polluted or polluted areas.

For minimum vertical clearances for new and existing structures, refer to the Trackway Clearances Chapter.

In assessing the minimum vertical clearance of the overhead structure, the vertical clearance between the overhead structure and the energized bare ATF cable shall also be considered.

Figure 21-7: Vertical Clearance Envelope at Fixed Structures



Source: AREMA Figure 33-2-3 and Figure 33-2-4

V	=	Total Vertical Clearance Required for Electrification
PA	=	Passing (Dynamic) Electrical Clearance – see Note below
U	=	OCS Uplift
T1	=	OCS Construction Tolerances
D	=	OCS Depth
B	=	Vehicle Bounce

Y = Static Vehicle Load Height
T2 = Track Maintenance Tolerance
CA = Static Electrical Clearance

Notes: The diagram depicts the dynamic condition. For static situations, the Static Electrical Clearance (CA) – refer to Table 21-5 - shall be not less than PA+U or PA+B

The minimum lateral clearance at fixed structures, including OCS poles and other OCS support structures and signal bridges, shall comply with the clearance requirements detailed in the Trackway Clearances Chapter.

21.14.11 Vehicle Clearances

Most railroads, including the commuter lines, adopt one or more of the standard Plate Diagrams issued by the Association of American Railroads (AAR) Mechanical Division in their Manual of Standards and Recommended Practice. For the purposes of these criteria, Caltrain's operating requirements and conditions have been assessed.

Passage of rail traffic over the Caltrain-owned right-of-way is governed by three Load Gauges:

- AAR Plate 'E' Height = 15' 11" MP 0.2 – MP 3.1 (San Francisco to UP's Quint Street Lead)
- AAR Plate 'F' Height = 17'- 0" MP 3.1 – MP 5.1 (UP's Quint Street Lead to Bayshore)
- AAR Plate 'H' Height = 20'- 3" MP 5.1 - MP 51 (Bayshore to Tamien)

For additional clearance requirements see Trackway Clearances Chapter.

Restrictions on the usage of Plate 'E & F' vehicles for the northern portion of the Caltrain ROW is mandated by the limited clearances in the four San Francisco Tunnels. Restrictions on the usage of Plate 'H' on the main portion of the route is mandated by the limited clearance at San Francisquito Creek Bridge in the city of Palo Alto.

21.14.12 Clearance to Buildings and Signs

Clearance to buildings and signs adjacent to right of way shall be as required by GO 95 rules 54.4H and 37 and Tables 1 & 2A.

21.15 OCS Structural Requirements

21.15.1 General

The OCS poles shall be either galvanized H-section wide flange beams, square tubes or galvanized round, tapered tubular steel sections. In designated areas and at passenger stations round, tapered tubular steel poles or square tube poles shall be used. All poles shall be of the bolted base type and shall be designed and manufactured to relevant U.S. steel standards and G.O. No. 95 strength requirements.

Where multiple OCS equipment are to be supported, such as at overlaps and turnouts, multiple cantilevers may be attached to a single structure, which shall be of a heavier section such that the applied loads shall not cause twisting of the structure by more than 5 degrees.

In double-track sections, the OCS poles shall be located outside the tracks with cantilever for support of the OCS. Center poles may be used in track areas where adequate clearance is available, and it is desirable to avoid property take issues or station platforms.

For multi-track areas where independent poles cannot be installed between tracks, portal structures with bolted base support poles and with drop tubes to support the OCS equipment related to individual tracks shall be used, thereby providing for mechanical independence of the individual equipment. Headspans can be used with prior approval from Caltrain.

In general, OCS poles in station areas shall be located between tracks. For situations where OCS poles must be located on station platforms, they shall be placed in a manner that minimizes the visual impact and obstruction to passengers, and shall be integrated with platform architecture design by being fully recessed. The minimum distance from platform edge to face of poles shall be 7 feet. Counterpoise grounding derived from local “drain bonds” or nearby impedance bond pairs shall be used within passenger stations, and the aerial static wire shall be electrically isolated from the OCS structures and components connected thereto.

The design of all OCS steel structures, poles and supports shall conform to the AISC, including relevant seismic requirements. The pole style shall be generally consistent through the project with Caltrain’s approval. Poles shall be designed as free-standing structures, except for poles carrying wire terminations, which shall be back-guyed, typically in the along track direction.

For balance weight poles, the balance weight can be placed inside the pole when round pole is selected, the weights are accessible, and the maintenance is considered and minimized through design. For poles on the passenger stations or within any urban design area, pole styles shall be in accordance with the requirements of the passenger station design and the urban design criteria. In all cases, the structures shall be designed to carry the OCS loads as outlined in these criteria, including additional imposed loading resulting from seismic events, without experiencing failure.

All structures, poles and brackets shall be capable of withstanding a broken-wire failure, including breakage of both the static wire and parallel feeder conductor in any one span, without exhibiting major, damage that will allow the OCS to fall to the ground. Deformation of the column to relieve the tension in the static wire and parallel feeder conductor is acceptable. The support structures shall be capable of handling the loads due to breakage of other parts of the OCS. Provisions shall be made in the designs to prevent overloading as a result of temporary construction loads imposed during catenary assembly and wire installation.

The pole length for each pole type shall be as uniform as practical to limit the number of required spares. Exceptions shall be considered on a case-by-case basis only when a standard pole length is deemed to be perceptibly inappropriate.

1. All steel materials, related processes and manufacturing methods shall be specified in accordance with ASTM standards, wherever applicable and deemed appropriate, including requirements for hot-dip galvanizing of steelwork and hardware. Painted pole shall not be precluded for poles on the passenger stations, within any urban design area, or in other special circumstances.
2. Anchor bolt patterns shall be selected to provide coordinated relationships between poles and foundations. The coordination shall be based on matching strength and minimizing the number of required configurations.
3. The poles on the platform shall be placed in a manner of minimizing the visual impact and passenger pass through obstruction, and shall be integrated with platform architecture design. Where a counterpoise grounding method is used within Railroad Passenger station, the aerial

static wire shall be electrically isolated from the OCS structures and components connected thereto.

21.15.2 OCS Pole and Foundation Requirements

The pole and foundation locations shall be designed in a manner that avoids conflicts with existing or planned overhead or underground obstructions. The OCS foundations shall be constructed in a manner that does not disturb the existing tracks under revenue service.

The loading assumptions and strength requirements shall meet or exceed the requirements of G.O. No. 95 rules. The general design loads include dead load, live loads - wind and earthquake load. However, as noted in NESC Rule 250A4, the structural capacity provided by meeting the loading and strength requirements of NESC Section 25 and 26 will provide sufficient capability to resist earthquake ground motions.

In addition to the load conditions indicated in G.O. No. 95 and the NESC, a 100 mph wind plus 10 percent gust allowance shall be evaluated to prove no structure failure.

All structures, poles, brackets, foundations and anchors shall be capable of handling construction loads imposed during erection and during catenary assembly and wire installation, and of withstanding a broken-wire failure, including breakage of both the static wire and parallel feeder conductor in any one span, without exhibiting major, catastrophic damage. These support structures shall also be capable of handling the loads due to breakage of other parts of the OCS. Pole and foundation loadings and structural designs shall be developed in accordance with the criteria defined herein. To facilitate aerial structure design, maximum loads for design of OCS pole foundation on aerial structures are specified in the Structures chapter.

The design of bolted steelwork connections shall conform to AISC requirements and shall specify materials and methods in accordance with ASTM standards. Anchor bolts (hold-down bolts) shall be galvanized.

OCS foundations and structures shall be designed so that their deflection under the loads imposed during normal operating conditions shall not cause a contact wire displacement that could prejudice acceptable tracking and performance of the pantograph current collector. To this end, the maximum allowable live-load operating deflection of the pole and foundation structure together shall be limited to 2 inches at the normal design contact wire height. For the purposes of structural design, this live loading shall be considered a dynamic operating condition, and the structure shall fully recover from its displacement due to the live loading.

For all non-operating loading conditions, excluding seismic conditions, the maximum total deflection of the pole and foundation together (measured at the pole top) shall not exceed 2.5 percent of the total pole length due to both static (dead) loads and live loads combined.

The foundation and steel pole, or vertical members of the support structure, shall be designed to enable the pole to be raked during installation. This rake shall allow for the static dead loads that are imposed on the structure by the cantilevers, equipment and along-track conductors. Rake installation shall provide for a visually plumb and vertical pole after application of the full static loading. This position shall serve as the design reference datum for the calculation of the live-load operating deflection. All OCS alignment and wire layout designs shall utilize this static, plumb, dead load position as the true pole-face reference datum.

The OCS foundations and poles shall be designed in a manner to minimize the number of types and sizes to simplify constructability, to avoid disturbing existing adjacent structures, to provide flexibility for pole rake adjustment, and to minimize future maintenance inventory and costs.

Anchor bolt patterns shall be selected to provide coordinated relationships between poles and foundations. The coordination shall be based on matching strengths and minimizing the number of required configurations.

Particular attention shall be given to the provision of a high level of protection against atmospheric pollution and contamination to maintain the design life without frequent maintenance cycles.

OCS support locations shall be individually numbered for ease of identification on site. Structure number plates shall be fitted to the structure at a height of 6 feet 6 inches (1.98 m) approximately above rail level.

21.15.3 OCS Poles

Poles shall be designed as free-standing structures, except for poles carrying wire terminations, which shall be down-guyed, typically in the along track direction. Caltrain Standard Drawing SD-2002, latest issue, is the governing criterion for pole to track clearance. For areas where UP Railroad clearances govern, clearance shall be in accordance with UPRR Standard Drawing 0038K, latest issue. Any variances from the standard spacing between the centerline of track and the face of pole shall be submitted to Caltrain for approval.

Aerial structures will be designed in a manner such that OCS poles can be located at any position along the structure. Alternatively, working in close coordination with the OCS Designer, aerial structures can be designed to provide site-specific locations for OCS pole installations.

The OCS supporting structures shall be calculated in accordance with relevant American standards (ACI, AISC, ANSI, ASCE, NESC). The allowance for a one-third increase in allowable stress for wind combined loading shall be waived.

The design of structural and fabrication welding shall conform to the AWS, Standard D.1.1, "Structural Welding Code".

Painted tapered tubular and square tube poles shall be used in passenger stations, as indicated on the OCS Layouts. The Painted Poles shall be hot-dip galvanized and have the proper surface preparation to receive a two coat powder finish. The Prime Coat shall provide corrosion resistance, chip resistance and adhesion. The Exterior Coating shall meet color, gloss and color requirements, and the coating system shall meet the technical specifications.

21.15.4 OCS Foundations

The OCS foundations shall be capable of meeting the structural loading requirements, and shall be designed for each individual location. The structural dimensions will be dependent on:

- Loads on the poles due to the OCS conductors, feeder cables, tensioning equipment, insulators, mid-point anchor ties, and all other necessary equipment.
- Wind loads on the poles and associated OCS conductors and equipment.
- Soil conditions.

- Earthquake loads.

OCS foundation designs shall be in accordance with ACI, AISC, and ASTM standards, other applicable codes, and proven foundation engineering and anchoring methods. Foundation designs shall consider buoyancy effects where applicable.

Augered, cast-in-place concrete foundations with a nominal diameter of 3 feet, 3 feet 6 inches and 4 feet, as shown on the Standard Drawings, shall be adopted for all normal situations. As an alternative pre-cast concrete foundations can be used as long as a minimum 3 inch concrete cover is maintained. Site-specific conditions or unusual loading combinations may dictate the adoption of other types or sizes of foundations. The permissible increase in soil resistance values, as defined in the CBC as being applicable to free-standing structures, shall be taken into consideration in the design of OCS foundations, in accordance with the CBC formulae.

The OCS foundations shall be designed to exceed the maximum design capability of the pole or structure being supported by the foundation by not less than 25 percent to ensure the foundation will not experience failure under the specified operating and non-operating conditions. The overturning moment shall not exceed 85 percent of the stability moment.

The foundation design shall incorporate the railroad E-80 freight load in any sheeting, shoring and foundation can sizing as needed. The Contractor shall perform geotechnical investigations and investigate soil characteristics. The Contractor shall design the slurry backfill to be used to suit the soil characteristics and drilling conditions to be encountered prior to starting installation of OCS foundations. The slurry design shall be modified, as necessary, to maintain adequate performance in various soil conditions.

The Contractor shall provide structural calculations for the proposed installation method showing that such a method of installation does not adversely affect the structural integrity of the tracks. The calculations and installation method will need to be reviewed per the provisions of the Contract by Caltrain.

The Contractor shall provide a set of installation procedures for review prior to construction. The procedures shall include the following details:

a. Step by step process from drilling through concrete placement, including procedures for slurry management and disposal.

b. Procedures for treatment of open holes at the end of a shift, including use of the specified temporary steel casings and caps for covering the tops of these casings.

c. Availability of spare temporary casings on site for use in case of unstable soil conditions and, when required, at the completion of shifts.

d. Adequate availability of equipment to preclude delay to operations resulting from Contractor installation delays.

Where fragmented rock is encountered, excavation shall be required for the installation of standard foundations. Where solid rock is encountered below grade (i.e., with soil cover), epoxy-grouted dowels shall be anchored to the rock (with appropriate pull-out tests being performed as required by the Contractor's engineer of record), and the upper portion of a standard anchor-bolt foundation cast into the soil. Where solid rock is encountered at-grade (no soil cover), the anchor bolts shall be epoxy-grouted into the rock (with appropriate pull-out tests being performed) as required by the Contractor's engineer of record) and with a small foundation-top cast around the bolts, primarily for corrosion protection and aesthetic effects.

Foundation height should be level with the top of high rail. The design of OCS pole foundations at station platforms shall be coordinated with the designers of any active station re-designs and shall be approved by Caltrain. When the OCS pole foundations are on platforms, the anchor bolts and base plate shall be fully recessed below platform level, and the void filled with grout as shown in the Standard Drawings. Special foundation heights may be employed in the railway cut sections and embankments to ensure foundations remain above the surrounding grade.

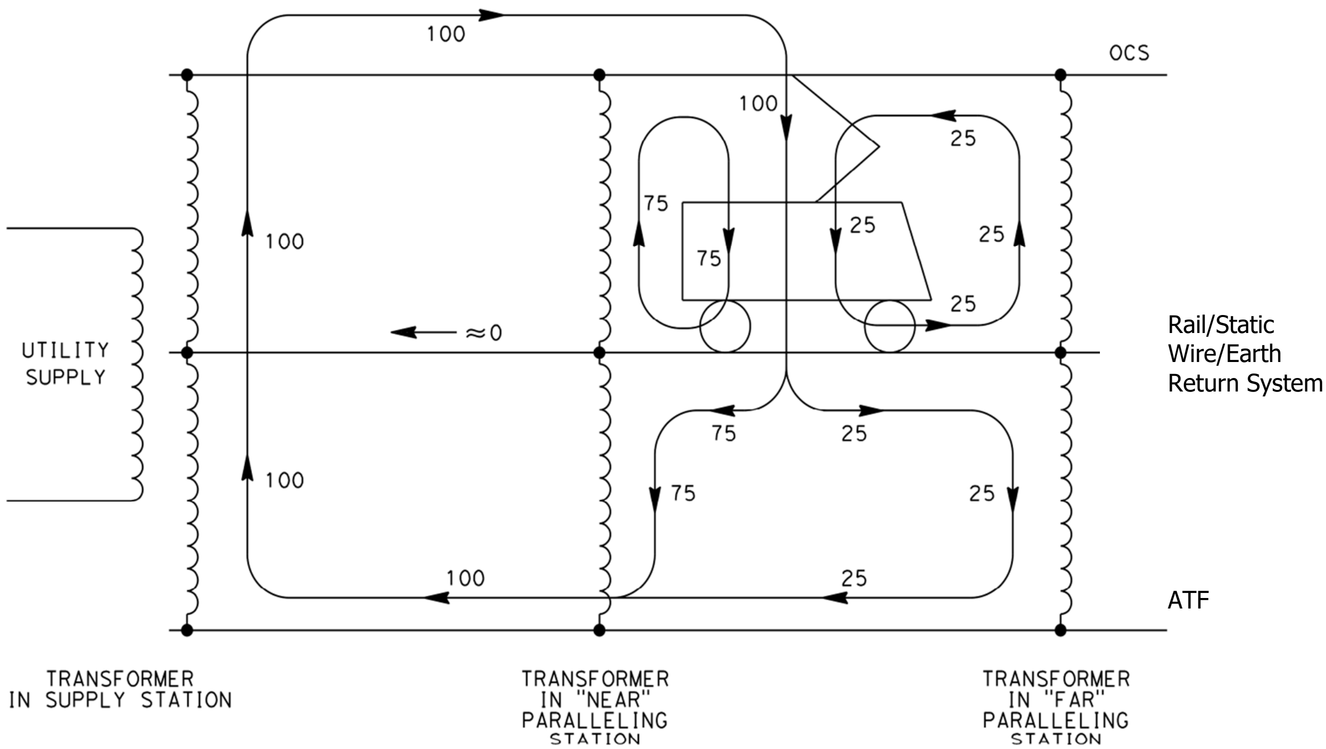
Existing geotechnical conditions shall be established by reviewing the existing soil data, local field testing, sampling and soils investigations. Information suitable for the design of foundations including any sheeting, shoring and foundation can sizing, shall be obtained regarding the soil strata conditions, state, uniformity, water content, weights and densities. Specific descriptions of the uniform layers, and their unique compositions, shall be provided at regular intervals along the ROW. These investigations shall also identify the sand and rock types encountered.

21.16 Traction Power Rail Return System

The Rail Return System comprises the running rails, impedance bonds, static or ground wires, return cables, and the earth, each of which provides a part of the electrically continuous return path for the traction currents (refer to Figure 21-8). The Rail Return System together with the Parallel ATF's comprise the Traction Power Return System, through which the whole traction current is returned from the wheel sets of the traction units to the substations.

The whole traction load current of a train operating between any two adjacent autotransformers flows through the rail return system within the bounds of these two autotransformers. These autotransformers, however, redirect a major portion of the traction load current into the ATF's, thereby minimizing the flow of return current in the rails in sections away from the train operating section. This is a safety related benefit of the autotransformer feed system; the other benefit being reduced electro-magnetic interference produced in this system as compared to the direct feed system.

Figure 21-8: Typical Proportional Current Distribution in a 2x25 kV Autotransformer System for a Train Current.



It is recognized that Figure 21-8 is a simplified diagram and is not an accurate representation of all current flows, since portions of the return current flow from the train location back to the substation via the static wires and earth. Most of the traction load current is carried by the OCS and ATF conductors, with residual return current being carried in the rail/static wire/earth return system.

21.17 OCS Interfaces with Other Disciplines

To achieve satisfactory performance of the OCS and current collection by the electrically-powered Caltrain vehicles, it is essential that the OCS Designer works closely with other disciplines. The following is not a totally inclusive listing, but provides guidance to the OCS Designer and indicates some of the major issues that must be addressed during the final design process.

21.17.1 Traction Power Supply System

Confirmation of traction power facility locations, and particularly of the TPSS and SWS where phase breaks are located.

Coordinate wayside power requirements and locations.

21.17.2 Rolling Stock

Confirmation of pantograph location on train consists and Freight Clearance Plates.

21.17.3 Train Control System

Coordinate locations of impedance bonds.

Coordinate signal sighting requirements.

21.17.4 Communications System

Coordinate wayside power cubicle requirements and locations.

Coordinate OCS disconnect switch RTU (Remote Terminal Unit) and interface requirements.

21.17.5 Overhead and Undergrade Bridges, Elevated Structures

Coordinate location of OCS poles and pole loadings.

Where the OCS design necessitates mounting structures and/or materials to grade separated structures, elevated structures and/or tunnels; the OCS Designer shall be responsible for:

1. Coordinating directly with the structure's / tunnel's owner and obtain formal permission.
2. Obtaining as-built design information from the structure's / tunnel's owner.
3. Generating OCS designs and submitting them for review and approval to the structure's / tunnel's owner

21.17.6 Trackwork

Coordinate locations of impedance bonds.

Confirm space requirements below rails for the installation of return cables and connections to impedance bonds.

END OF CHAPTER

Chapter 22 Grounding and Bonding Requirements

Acronyms

AC	Alternating Current
CIC	Communications Interface Cabinet
EMI	Electromagnetic Interference
IEC	International Electrotechnical Commission
MOI	Maintenance of Infrastructure
O&M	Operations and Maintenance
OCS	Overhead Contact System
OSP	Outside Plant Cable
PTC	Positive Train Control
RGB	Rack Grounding Busbar
SRG	Signal Reference Grid
STP	Shielded Twisted-Pair
TBB	Telecommunications Bonding Backbone
TBBIBC	Telecommunications Bonding Backbone Interconnecting Bonding Conductor
TGB	Telecommunications Grounding Busbar
TES	Traction Electrification System
TPF	Traction Power Facility
UL	Underwriters Laboratories, Inc.
WPC	Wayside Power Cubicle

22.1 Scope

Grounding, Bonding, and Lightning Protection shall be designed to address three purposes: (1) personal safety; (2) equipment, cabling and building protection; and, (3) equipment noise reduction. This chapter addresses the first two items, and equipment noise reduction is addressed in the Electromagnetic Compatibility and Interference chapter. Grounding and bonding design shall be compatible with the requirements of the Electromagnetic Compatibility and Interference chapter.

This chapter also provides criteria for the electrical separation of outside utility lines from the traction return and grounding systems.

Grounding is the establishment of a common reference voltage (typically 0 V) between power sources and/or electrical equipment. Electrical ground faults, short circuits, lightning, and transients can occur in electrical power supply and distribution systems or the facilities power systems. These design criteria specify requirements for the protective provisions relating to electrical safety in structures associated with the alternating current (AC) traction system and to any structures that may be endangered by the traction power supply and distribution systems or the facilities power system, and to any Communications Based Overlay Signal System/Positive Train Control (PTC), communications, or other electronic equipment that must be protected from electrical shocks. The grounding of PTC, communications, and other electronic equipment sensitive to high currents and/or voltages is also covered in this chapter. Grounding systems are intended to help clear faults in the quickest possible manner by providing a low impedance path for fault currents.

Grounding, Bonding, and Lightning Protection is multi-disciplinary in nature. The design shall consider and mitigate the negative effects of lightning, ground potential rise, contact with electrical power circuits, and induction. The various discipline designers must collaborate with one another to coordinate the overall grounding and bonding design, so that a consistent approach is used and applied by each discipline in the development of the electrical, power and structural grounding and bonding and lightning protection.

Where multiple codes address the same issue, but specify differing approaches or values, the most stringent requirement shall be met.

In addition, this chapter provides criteria for designs that will minimize the touch voltage and ground return currents created by the electrification system and facilities electrical systems that will provide for the safety of passengers and operating personnel and minimize the hazards of electrical shock. The grounding and bonding system designs shall provide the means to carry electric currents into the earth under both normal and fault conditions without exceeding any operating and equipment limits or adversely affecting continuity of service.

For AC traction systems, grounding is the preferred method for reducing potentials of the electrical system both during normal operations and under fault conditions to protect equipment and to provide safety for employees and the general public. Adequate bonding shall be designed and installed throughout the entire electrified system to provide proper return circuits for the normal traction power currents and fault currents, with grounding connections as detailed in these criteria.

In principle, to assure the integrity of the grounding and bonding systems and the longevity of the system components, particularly for buried or encased elements, the bonding and grounding designs shall create duplicate electrical continuity paths and provide for redundancy in jumpers and bonds.

Design documents shall identify each type of ground connection, consistent with the ground categories identified in the Electromagnetic Compatibility and Interference chapter and as indicated in the following sections.

22.2 Regulations, Codes and Standards

- California Code of Regulations, Title 24 (California Building Standards Code which includes the California Electrical Code)
- California Public Utilities Commission (CPUC) General Order (GO) 95
- International Electrotechnical Commission (IEC) 60479: Effects of Current on Human Beings and Livestock – Part 1 General Aspects
- Institute of Electrical and Electronics Engineers (IEEE)

  IEEE Std. 80: IEEE Guide for Safety in AC Substation Grounding

  IEEE Std. 81: IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Part 1)

  IEEE Std. 142: IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)

  IEEE Std. C2: National Electrical Safety Code

  IEEE Std. 1100: "Recommended Practice for Powering and Grounding Sensitive Electronic Equipment"

  IEEE Std. C62.41: "IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits"
- American National Standards Institute (ANSI): ANSI-TIA-EIA-607-A "Grounding and Bonding Requirements for Telecommunications in Commercial Buildings"
- National Fire Protection Association (NFPA)

  NFPA 70: National Electrical Code

  NFPA Std. 780: Standard for Installation of Lightning Protection Systems
- European Standards (EN)

  EN 50119 - 2001: Railway Applications – Fixed Installations – Electric Traction Overhead Contact Lines

  EN 50122-1 - 2011: Railway Applications – Fixed Installations - Part 1. Protective provisions relating to electrical safety and earthing

  EN 50124-1 - 2001: Railway Applications – Insulation Coordination – Part 1. Basic requirements – Clearances and creepage distances for all electrical and electronic equipment
- The Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA Manual)
- Underwriters Laboratories (UL)
- U.S. Department of Defense (USDOD) Military Standards

22.3 General Grounding and Bonding Requirements

A uniform/standardized grounding and bonding system design shall be adopted to provide for protection of personnel and equipment. All grounding and bonding designs shall be coordinated with the various discipline designers, including civil, architectural, electrical and electronic, mechanical, plumbing and systems, such as traction power supply and distribution, communications, PTC, etc.. Refer to respective Sections of this Design Criteria for specific grounding and bonding requirements. All grounding and bonding designs shall be coordinated with the stray current and corrosion control measures, and with the electromagnetic compatibility and interference requirements, so that the respective designs do not conflict and render other systems ineffective.

Exposed non-current carrying conductive parts within the Overhead Contact Line Zone (OCLZ), such as conduit, cable trays, handrails, trackside fencing, etc. shall be electrically bonded to provide a continuous electrical path, and shall be permanently and effectively grounded. Grounding system designs may include the grounding of individual items, and/or dividing the length of non-current-carrying conductive entities into sections with each section grounded at only one point. Grounding and bonding conductor sizes shall be selected in accordance with the latest version of the applicable code. For the specific ground resistance at each grounding location, apply the requirements in respective sections of this document.

An electrical safety analysis shall be undertaken to assess which metallic parts need to be grounded and bonded, and the appropriate methodology for implementation identified. Non-current carrying parts that are used as part of the existing utility electrical distribution system, such as conduits, cable trays, manholes are assumed to have grounding in accordance with the National Electrical Code.

Grounding/Bonding requirements for wayside electrical equipment (in addition to fences and other metallic objects) within the OCLZ are generally equalized with the traction return system in addition to earth ground. There shall only be one connection to the traction return system via use of a buried counterpoise conductor(s) and a single connection to an impedance bond for equalization to the traction return network.

Grounding/Bonding requirements for wayside electrical equipment and other metallic items (fences, etc.) outside the OCLZ shall not be connected to the traction return system, but be grounded to earth in accordance with Caltrain's standards and as described herein.

22.3.1 General Facility Grounding

The design of each large facility/building shall include a ground grid. Wayside houses shall be grounded by means of one or more interconnected ground rods. Where ground grids are used, the design shall adhere to the following requirements:

Ground grid design shall be based on local soil resistivity and the calculations shall be in compliance with IEEE standards (e.g., 80, 142, and 1100) and the CEC/NEC/GO 95/NESC rules as applicable.

Ground grids shall be constructed from an assembly of driven ground rods and bare copper conductors, installed adjacent to but not under the building, and shall achieve a ground resistance of not more than 5 ohms. A continuous loop of the grounding conductor(s) shall surround the perimeter of each facility/building, to which the perimeter fence and gates (where provided) shall be effectively bonded at frequent intervals, and within this loop the conductors should be laid in the form of a grid. At the cross-connections, the conductors should be securely bonded together by means of exothermic welds.

Ground rods shall be installed at grid corners, at junction points along the perimeter, and at major equipment locations with the ground rods being driven vertically into the ground to not less than the minimum depth specified in NESC (2007) Rule 094B2a.

Horizontal ground rod configurations may be required where subsurface rock or other obstructions interfere with the placement of vertical ground rods.

The ground conductors may be made of copper or other metals/alloys that will not corrode excessively during the expected service life.

Ground rods may be of zinc coated steel, stainless steel, copper-clad or stainless steel-clad steel. The ground conductors shall be securely bonded to the ground rods and to the equipment (including busbars) to be grounded. Joints shall be exothermically welded.

- The ground rods shall be driven to stable soil where constant conductivity properties apply.
- At least 2 ground test stations shall be provided at each ground grid.
- Ground test stations shall be incorporated into the design of the ground grids. Each ground test station shall be connected to the ground grid by at least two grounding conductors.
- Ground test stations shall be located so that they are accessible to Operations and Maintenance (O&M) personnel. Locations shall be chosen that minimize the bonding conductor length.
- Supplemental electrodes (at equipment) shall not be permitted.
- The ground grid shall be bonded to the AC service ground electrode and the structural steel of the building structure.
- Ground grid locations shall be coordinated with landscaping plans to avoid conflicts with tree roots, and with underground utilities and sewer installations to avoid any direct electrical connection to these systems.
- Ground grids shall be designed to allow up to 50 percent additional ground rods to be driven and attached to the grid in the future.

22.3.2 Ground Busbars

Unless otherwise specified, a single ground busbar shall be provided in each equipment room and pre-engineered enclosure (e.g. traction power facility (TPF) equipment houses, communications rooms, PTC /signal houses, and wayside power control cubicles).

Ground busbars shall comprise a solid copper grounding busbar with insulated standoffs, and each ground busbar shall be drilled with rows of holes according to National Electrical Manufacturers Association (NEMA) standards, for attachment of bolted compression fittings.

Additional ground busbars for equipment shall be provided such that no potential equipment location within an auxiliary space (housing the equipment) is more than 30 feet from the nearest ground busbar.

Ground conductors at ground busbars shall be identified as to which system they are connected.

The ground busbars shall be connected to the ground electrodes or ground grids as detailed in Section 22.5.

22.3.3 Non-buried Grounding Conductors

Non-buried conductors between the ground grid or ground busbar and the grounded equipment shall be insulated copper wire or cable in non-metallic conduit. Grounding and bonding conductors shall be sized in accordance with the applicable code, so they can pass the maximum ground fault current without melting or fusing before the circuit breakers or protective relays disconnect the source of the fault current.

Non-buried grounding conductors shall be protected against physical damage and accordingly routed in conduit, cable tray systems, cable troughs, and/or ductbank systems under the following scenarios:

- Between buried ground grids and ground test stations.
- Between ground test stations.
- Between ground test stations and ground busbars.
- Between equipment enclosures and grounding busbars.
- Between equipment enclosures.
- Along the trackside.

Non-buried grounding conductors shall be antitheft approved by Caltrain.

22.3.4 Publicly Accessible Locations

For locations that are accessible to the public, the following constraints shall apply to the grounding and bonding design:

- Anchor bolts and ground lugs shall not protrude in a manner that could result in injury or property damage.
- Materials shall be concealed wherever possible.
- Ground test stations in public areas shall be avoided.
- Tamper proof hardware shall be used.

22.3.5 Grounding Connections

Exposed grounding and bonding connections at equipment, enclosures, ground busbars, ground test stations, and so forth shall be visible and accessible. Two-hole compression-type termination lugs shall be used to connect bonding conductors to equipment enclosures.

Buried/underground joints in grounding conductors and connections shall be exothermically welded. Connections to reinforcement steel shall be exothermically welded.

Epoxy coated rebar cannot be used as a grounding conductor. Where epoxy coated rebar is used as the only type of reinforcement, alternate grounding measures, such as connecting grounding plates directly to a series of buried ground rods or a ground grid, shall be adopted to achieve the required ground resistance.

The required ground resistance shall be achieved, if necessary, by connecting the grounding plate(s) directly to buried ground electrodes. Splices in grounding conductors will not be permitted.

Equipment enclosure doors shall be bonded with flexible metal bonding straps, instead of reliance on hinges for electrical continuity.

Where identical installations exist, the following requirements apply wherever practicable:

- The routing of conduit and conductors between structures and enclosures shall not differ.
- Conductor terminations shall be located in like manner.

Prescribed materials, cables and appurtenances shall be compliant with Underwriters Laboratories, Inc. (UL) standards.

Water, gas or other piping shall not be utilized as a ground electrode or ground conductor.

22.3.6 Electromagnetic Compatibility

For electromagnetic compatibility considerations, provide:

- Proper grounding and bonding of apparatus, conductor shields, and raceways to maximize shielding and to minimize circulating currents in shields.
- Surge protection against lightning and other natural sources of Electromagnetic Interference (EMI).
- Additional requirements are specified in the Electromagnetic Compatibility and Interference Design Criteria.

22.4 Maximum Permissible Step and Touch Potential

Step and touch potential at the traction power facilities and facility power electrical rooms and/or yards shall be governed by the requirements of IEEE 80: Guide for Safety in AC Substation Grounding.

The bonding and grounding of current carrying equipment, enclosures and associated structures, including the Overhead Contact System (OCS), rails, and other trackside equipment, shall be designed such that the touch voltages do not exceed the values indicated in Table 22-1, which has been derived from EN 50122-1: 2011 Section 9.2.2:

Table 22-1: Durations of Maximum Permissible Touch Voltages

Duration of Current Flow (sec)	Permissible Voltage in V (rms)
0.02	865
0.05	835
0.1	785
0.2	645
0.3	480
0.4	295
0.5	220
0.6	180
< 0.7	155
0.7	90
0.8	85
0.9	80

1.0	75
300	65
> 300 (where accessible to the public under all power supply feeding conditions)	60
> 300 (in workshops and similar locations)	25

In areas where the Union Pacific Railroad operates on an adjacent non-electrified track, the maximum permissible voltage shall not exceed 50 Volts (rms).

22.5 Grounding and Bonding Requirements for Facilities/Buildings and Structures

22.5.1 General Requirements

Structure grounding and bonding shall create a conductive path that will achieve potential equalization of the grounded elements of the railway system. The grounding system provides grounding connections for:

- High/medium-voltage protective ground.
- Low-voltage protective ground.
- Communication and signaling systems.
- Lightning protection ground.

Any non-energized component of structures within the OCLZ and pantograph zone (see Section 22.6.3) shall be either directly grounded or be bonded to running rails via an impedance bond pair or "drain bond" to provide for personnel safety.

Bonding to pre-stressed steel tendons, within structures, is prohibited.

22.5.2 Facilities/Buildings

<u>Service Entrance and Building Grounding</u>

The AC grounding electrode system (otherwise known as "building ground", "service entrance ground") shall be designed to:

- Establish a common reference voltage for AC electrical power systems
- Provide a safe dissipation path for lightning and/or accidental high-voltage contact
- Provide a safe dissipation path for electrostatic discharge.

The components that make up the AC grounding electrode system include:

- Grounding electrode system (ground rod or ground grid)
- Grounding electrode conductor
- Bonding Conductor connects equipment grounding systems to the AC grounding electrode

A ground grid (see Section 22.3.1 for requirements), in direct contact with the earth at a depth below the earth surface of at least 3 feet, shall be provided at each building. The ground grid shall extend at least 2 feet beyond the foundation footer and at least 1 foot 6 inches outside the roof drip line.

The metal frame of buildings shall be bonded to the ground grid. Connections to the ground grid shall be exothermically welded. Where exothermic welding is impractical, UL listed connection hardware may be used.

For steel-frame buildings, alternate vertical columns shall be bonded to the ground grid.

Building Exterior and Interior Bonding and Grounding

Wherever a grounding conductor passes through a structure, foundation or wall, waterstops shall be provided.

Multiple separate grounding systems are not permitted within the same building. Where a building is supplied by two or more services, the grounding electrodes for the two services shall be bonded together.

In multi-floor buildings, the grounding conductor shall be extended to each floor.

Provide a grounding electrode conductor sized in accordance with the applicable code between the service equipment ground bus and metallic water and gas pipe systems, building steel, and supplemental or made electrodes. Jumper insulated joints and bolted (non-welded) joints in the metallic piping.

Bond the steel columns to the reinforced steel within the building foundation.

Conductive piping systems shall be bonded to the building grounding system. Bonding connections shall be made as close as practical to the equipment ground bus.

Within a building, the grounding cable shall, where possible, be embedded in or underneath the floor slabs. Attach and bond the grounding electrode system to non-current-carrying conductive entities within the building.

22.5.3 Raised Floor Systems

A Signal Reference Grid (SRG) shall be provided for raised floor systems in compliance with IEEE 1100 and with the requirements of the Electromagnetic Compatibility and Interference chapter.

Connect the SRG to the facility grounding electrode system.

Where raised floor systems are of bolted metal stringer construction and are electrically continuous, two connections only to facility grounding electrode system shall be required.

22.5.4 Grounding and Bonding of Structures - General

Except for passenger station and service siding platforms, metallic items on structures crossing over, under or immediately adjacent to the electrified tracks shall be bonded either directly or indirectly to a static wire or to the running rails of the adjacent track through an impedance bond for personnel safety and lightning protection. Epoxy coated rebar cannot be used as a grounding conductor. Where epoxy coated rebar is used as the only type of reinforcement, alternate grounding measures, such as connecting grounding plates directly to a series of buried ground rods or a ground grid, shall be adopted to achieve the required ground resistance. Where epoxy coated rebar is used in combination with black rebar, the black rebar shall be interconnected to provide an electrically continuous path, with connection(s) to grounding plate(s), but with no connection to the epoxy bar. The required ground resistance shall be achieved, if necessary, by connecting the grounding plate(s) directly to buried ground electrodes. The grounding and bonding of the emergency walkway area and other publicly accessible areas, as well as grounding and bonding of the track structure (where appropriate), shall be designed to avoid inadmissible touch and step voltages and also to meet the requirements of the signaling system.

22.5.5 Passenger Station and Service Siding Platforms

<u>Passenger Stations and Service Siding Platforms in At-grade, Cut-and-Cover Tunnel, or Trench Locations</u>

For at-grade platform grounding, a counterpoise shall be installed along the entire length of each platform with the conductor buried in earth and extending a minimum of 50 feet beyond the ends of the platform. Bond all metallic objects, structures and miscellaneous items capable of picking up induction or carrying fault current, located within 8 ft from the edge of the platform or a grounded object, to the counterpoise or grounding conductor, including catenary support columns and platform reinforcement (Exception: metallic objects smaller than 6′ perpendicular to track by 8 ft parallel to track need not be bonded). The platform steel reinforcement shall be interconnected electrically by means of exothermic welds and shall be electrically continuous. The catenary columns in the passenger station shall be electrically isolated from the static wire.

In addition, for cut-and-cover tunnel or trench located platform grounding, where the structure is protected by waterproof membranes, an in-ground counterpoise cannot be installed. For these locations, a bare grounding conductor shall be installed along the entire length of each platform with intermediate connections to the platform reinforcement at not more than 200-foot intervals. The ends of this conductor shall extend a minimum of 50 feet beyond the ends of the structure buried in earth and connected to driven ground rods. The grounding conductor shall be a minimum size of 4/0 AWG copper, but alternate materials, such as aluminum angle of comparable electrical capacity, may be adopted. Appropriate measures shall be adopted where dissimilar metals are interconnected.

In all station platform types (at-grade, cut-and-cover tunnel or trench located platforms) one end of the counterpoise or grounding conductor shall be terminated in a handhole, which will permit the counterpoise or grounding conductor to be connected to the rails via an impedance bond, with the location being coordinated with the PTC System designer. Metallic structures and miscellaneous metallic items including platform reinforcement steel and any OCS poles, as well as items larger than 6′ perpendicular to track by 8′ parallel to track within 8 feet from the edge of the platform shall be isolated from the static wire and shall be bonded directly or indirectly to the counterpoise or grounding conductor. The counterpoise or grounding-conductor-bonded metallic items shall be isolated from steel building grounds and particularly from utility grounds.

The grounding design shall ensure the maximum permissible touch voltages, as specified in Table 22-1, are not exceeded and, without exception, the resistance to ground shall not exceed 5 ohms. Subject to field testing during construction, it may be necessary to install supplemental ground rods at the ends of the counterpoise to achieve the 5 ohm value, and the designer shall incorporate this requirement in the design.

See Sections 22.5.2.1 and 22.5.2.2 for the Grounding and Bonding requirements for facility power installations in passenger stations.

22.5.6 Existing Overpasses

If components of existing overpasses, as detailed below, lie within the OCLZ and pantograph zone, see Figure 22-1, the following special grounding provisions may be required to afford protection to adjacent third party installations:

- Abutments or Piers – galvanized steel strip on each bridge wall or attached to columns or piers.
- Bridge Face – galvanized steel strip or angle section above the overhead line at each bridge face, if the bridge soffit is within the pantograph zone.

The above measures shall be provided at existing structures if an analysis determines the need for them.

When the vertical clearance between OCS conductors and concrete overpasses is less than or equal to 3 feet, protection panels (flash plates) shall be installed above the OCS, attached to the underside of the structure, and interconnected to the static wire at not less than two locations. For steel overpasses, the steel girders shall be interconnected and bonded to the static wire at not less than two locations.

Publicly accessible overpasses shall be protected by screening and/or barriers which shall be at least 9’-6” high and extend laterally beyond, and normal to the live parts of the Overhead Contact System by at least 10 feet on each side. The metallic portion of the screening and barriers shall be bonded to the static wire at not less than two locations. All other metallic items on the overpass, within the lateral range of not less than 10 feet beyond any energized and uninsulated equipment passing below the structure, shall be directly or indirectly bonded to the static wire.

22.5.7 Screen/Noise/Wind/Safety Barriers

The metallic portions of screen, noise, wind and/or safety barriers shall be electrically connected in a similar manner to that detailed above for aerial structures.

Safety barriers shall be electrically bonded to the static wire at not fewer than 2 locations.

22.5.8 Fence and Gate Grounding

The designer shall evaluate touch voltages on metallic fences and/or gates, including inter-track fences, which lie within the Overhead Contact Line and Pantograph Zone (Figure 22-1). Ground electrodes shall be installed on either side of a gate or other opening in the fence. Fence posts at openings in the fence shall be bonded to form a continuous path, and gates shall be bonded to support posts with flexible metal bonding straps to eliminate reliance on hinges for electrical continuity. Fences shall be made electrically continuous and grounding conductors shall be exothermically welded to fence posts and to any fence material support members (top and bottom) between posts. Ground rods shall be applied at regular intervals to metallic fences for their entire length. The distance between ground rods shall be dependent on the step-and-touch potential as measured.

Metallic fences outside the Overhead Contact Line and Pantograph Zone (Figure 22-1), up to a distance of 45 feet from an outside track centerline, shall be bonded to form a continuous path in the same manner as detailed above. Ground electrodes shall be installed on either side of a gate or other opening in the fence, and at intermediate locations, based on local soil resistivity and worst case projected potentials. Grounding conductors shall be exothermically welded to fence posts and to driven ground electrodes.

22.5.9 Third-Party Grounding Interface

Due to the danger of voltage propagation, third-party grounding installations in the vicinity of the ROW shall not be connected to the railway grounding system. For third-party pipework, non-conducting materials shall be used, or an insulating segment or insulated joint shall be inserted at the site boundary. Where the public network grounding system cannot be separated from the railway grounding system due to lack of space for separation, the traction power return circuit shall be interconnected with the neighboring grounding system of the public network.

To minimize the possibility of shock hazards outside the fence line, the systems designer shall evaluate touch potentials on third-party metallic fences/gates and/or pipelines that parallel the ROW, or other metallic structures. The systems designer shall provide designs for grounding and/or segmenting the conductive feature using insulating measures for these elements, such that touch potentials are controlled to levels that do not exceed the limits detailed in Table 22-1. Fences, and/or segments shall be made electrically continuous, but shall not be connected to railway ground grids, grounding conductors, static wires, or the rails, and shall be independently grounded by means of driven ground rods. Grounding conductors shall be exothermically welded to fence posts and to driven ground electrodes.

In cases where fences are purposely electrified to inhibit livestock or wildlife from crossing the fence, site-specific insulating measures shall be designed and implemented.

Connections to third-party infrastructure shall be coordinated and approved by the third party. Refer also to Section 22.12 and to the Utilities chapter.

22.6 Grounding and Bonding Systems for the Traction Electrification System Equipment and Structures

22.6.1 General

The rail return path of the 2x25 kV AC autotransformer feed Traction Electrification System (TES) consists of the static wires, the running rails, cable connections from static wires/running rails to the TPF (all of which are grounded as detailed below) and the earth. The static wire is connected at regular intervals to the running rails, via impedance bonds, to help reduce step-and-touch potentials, but must be coordinated with the signal system to ensure that broken rail protection is not compromised. The static wire runs alongside the catenary to interconnect the OCS supporting structures (except at station platform areas), signal bridges and masts, overhead bridges and is connected to the Traction Power Facilities ground busses.

The traction return current causes a voltage rise in the running rails and static wires, due to the impedance of these conductors, for both normal operations as well as under short circuit conditions, thereby resulting in a voltage between the running rails and static wires and the surrounding ground or other grounded metallic parts (touch voltage). These touch voltages shall be limited to acceptable values. Hazards due to touch voltages shall be minimized by means of adequate grounding and bonding measures, and as required, mitigation measures.

For a more detailed description of the TES, refer to the Traction Power Supply System and Overhead Contact System and Traction Power Return System chapters.

The overall grounding and bonding protection for the TES shall consist of the OCS aerial static (ground) conductors, connections from the aerial ground conductors to any buried ground conductor/ground rods and the impedance bonds connected to the track, with connections between these elements and each

TPF ground grid. In addition to the impedance bond connections at the TPF's, additional connections between the static wires and the rails through impedance bonds may be needed, based on the traction power load flow simulation results and the step and touch analysis. The designer shall determine the required spacing of the impedance bonds and interconnections to the rails, which must be coordinated with the operating requirements of the PTC System.

Where insulated cables are used within the TES, they shall be specified and manufactured in accordance with the appropriate electrical standards that are applicable to the working environment—voltages, operating and fault currents—to which they will be subjected.

The OCS grounding and bonding system shall interconnect all OCS normally-non-current-carrying metallic parts and shall bond metallic components of overhead bridges, tunnels and other structures.

The grounding and bonding system for the TES shall not be electrically connected to any non-traction power facility electrical grounding system.

22.6.2 Traction Power Facilities

See Section 22.5 for general ground grid requirements.

The ground grid for each TPF shall be in direct contact with earth at a depth of 12 to 18 inches below grade, as stipulated in IEEE-80: 2000, Section 9.2. The ground grid shall be extended at least 2 feet beyond the fence of the TPF. The ground grid for each TPF shall be designed per the specifications of IEEE-80, NESC, CEC and NEC.

The metal fence of the TPF shall be bonded to the TPF ground grid as specified in the applicable code.

A layer (3 to 6 inches thick) of high resistivity material, such as gravel, shall be spread on the earth's surface above the ground grid to increase the contact resistance between the soil and the feet of persons in the TPF. The grounding system shall be designed so that the step and touch potentials under fault conditions are within the designated limits.

In areas where soil resistivity is high or the TPF space is limited, alternative methods shall be considered for obtaining low impedance grounding, such as connections to remote ground grids or wire mesh, deep-driven ground rods or drilled ground wells, plus the use of various additives and soil treatment methods, etc. The effects of transferred potentials, which can result from interconnection to remote ground grids, shall be considered.

Wayside Power Cubicles (WPC) in at-grade locations shall be grounded by separately driven ground rods at opposite corners, which are to be connected to grounding pads on the enclosure. For aerial locations and in tunnels, trenches, retaining wall and retained fill structures, the WPC shall be grounded by two interconnections to a grounding plate (as detailed above for the aerial structures).

22.6.3 Overhead Contact System

OCS structure grounding and bonding should create a conductive path that will achieve potential equalization of the grounded elements of the railway system. Grounding connections provide for tying wayside metallic parts to the return circuit and for the electrical interconnection of reinforcing rods in concrete structures, and in case of other modes of construction, the conductive interconnection of the metallic parts. The structure grounding system provides grounding connections for the following:

- High/medium-voltage protective ground

- Low-voltage protective ground
- Grounding of telecommunication and signaling systems
- Lightning protection ground

Except at Station Platform areas the OCS poles shall be grounded through interconnection of the pole to the static wire so that the ground resistance of the interconnected poles is kept low. Reinforced concrete and anchor bolt foundations, where the concrete is in good contact with the adjacent soil, are recognized as being good earth electrodes. Where the ground resistance of individual OCS poles exceeds 25 ohms, individual ground rods or other grounding solutions shall be applied. All other OCS structural supports—wall brackets, drop pipes, feeder wire brackets, etc.—shall be interconnected to the static wire.

Ground connections to disconnect switches and ground leads from surge arresters shall have a maximum ground resistance of 5 ohms. Ground rods or a ground mat may be utilized to obtain the required ground resistance.

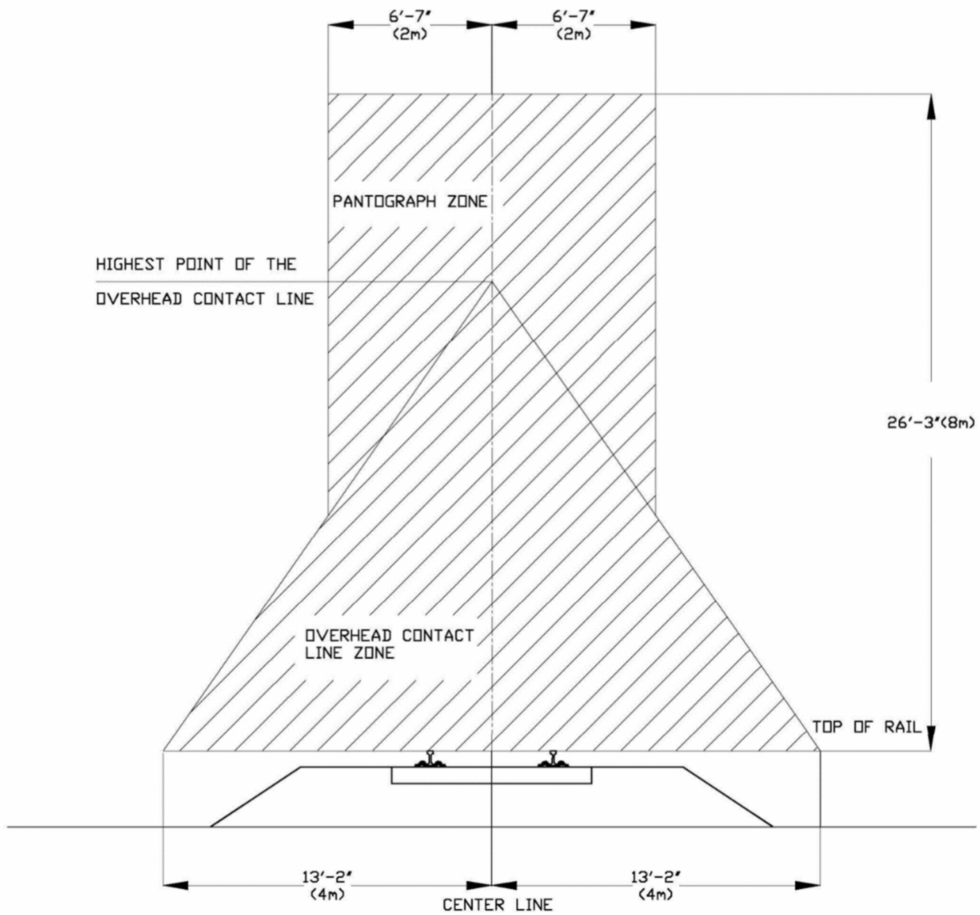
See Section 22.7 for additional requirements.

A live broken contact line, or live parts of a broken or de-wired pantograph or energized fragments, may accidentally come into contact with wayside structures and equipment. Figure 22-1 defines the zone inside which such contact is considered probable and which limits are unlikely to be exceeded, in general, by a broken overhead contact line or damaged energized pantograph, or energized fragments.

The limits of the overhead contact line zone below top of rail extend vertically down to the earth surface, except where the tracks are located on a viaduct where they extend down to the viaduct deck. In the case of energized out-of-running OCS conductors, the overhead contact line zone shall be extended accordingly.

Permanent, non-current-carrying metallic components that lie within the overhead contact line and pantograph zone shall be either directly grounded or bonded to the static wire to provide for personnel safety.

Figure 22-1: Overhead Contact Line Zone and Pantograph Zone



22.6.4 Return System

The ground grid at each traction power facility, and the center tap of the secondary of main power transformers and the center tap of autotransformers, shall be connected to the traction power facility ground bus. The ground bus shall be connected to the rails through impedance bonds, and to both static wires through two independent connections. The return cable shall be sized to carry the maximum load current, thereby allowing for the failure of one return cable. The static wire shall be connected at regular intervals to the running rails, via impedance bonds at locations approved by the PTC designer. Additionally, the impedance bonds shall be cross-connected at intervals in both two-track and multi-track areas at a frequency that does not compromise the broken rail detection system.

This aspect of the grounding and bonding system design shall be coordinated between the Traction Power Supply System, OCS and PTC designs.

22.6.5 DC Traction Systems Adjacent to the Caltrain Right-of-Way

Where tracks operated by DC traction power systems are located adjacent to the tracks, a considerable degree of coordination will be required with the DC traction system operator to minimize the possibility of creating DC stray current circuit paths through the AC system traction power return circuits.

The design of the TES shall minimize the possibility of creating DC stray current circuit paths through the return system. The static wire in the area potentially subject to DC stray currents shall be electrically insulated from the OCS poles by supporting the static wire on insulators. The OCS poles shall be grounded through interconnection of the pole, anchor bolts and steel reinforcement of the concrete foundation so that the ground resistance of individual poles is kept low, and does not exceed 25 ohms. Where the ground resistance of individual OCS poles exceeds 25 ohms, individual ground rods or other grounding solutions shall be applied. Fault conditions shall be evaluated, and grounding designs shall be developed such that unsafe touch voltages are not created.

The designer shall monitor and document any DC stray current leakage from DC system tracks adjacent to the Caltrain right-of-way/facilities during the design phase to establish baseline levels. Similarly, the contractor shall monitor and document any DC stray current leakage from the DC system tracks during the field testing and commissioning phase, to evaluate any differences and take any necessary remedial action to assure the integrity of the system.

Where passenger platforms and emergency walkways are located adjacent to DC system tracks, the designer shall investigate whether inadmissible touch voltages could occur between the rail and ground, and shall determine whether a voltage-limiting device, such as non-permanent rail to ground connection, should be installed to control touch voltages. If necessary, the designs shall require the contractor to install such devices.

All of the above measures shall be coordinated with the PTC System designer.

Early in the design phase, Caltrain will have to coordinate with the DC electrified railroad operator to obtain assurance that the operator will maintain a high level of insulation between the DC system rails and ground in these sections to minimize the possibility of any DC stray currents leaking into the AC traction return system.

22.7 Grounding and Bonding Protection Systems for the Signaling & Train Control System Equipment and Structures

22.7.1 PTC Houses and PTC Rooms

Ground grid and risers to the PTC rooms in stations shall be included in the facilities design, and shall stub out 6 inches above the floor inside the PTC room.

Ground rods or ground grid and risers to the PTC houses and cases shall be provided by the ATC contractor where these units are located at grade.

The grounding system for PTC equipment shall be designed as a single-point ground system. Equipment safety grounding shall be designed to limit touch voltages to safe levels, as specified in Table 22-1, with and without a fault on the AC system.

Solid copper ground busbars designed for mounting on the framework of open or cabinet- enclosed ATC equipment racks shall be provided. Ground bars, within equipment racks, shall be bonded together using solid copper splice plates. All busbars and the metal structure of the houses and cases shall be bonded to the ground conductor, which in turn shall be bonded to the local ground provision (either ground rods or grounding plate integrated into the civil structures.

Bonding conductors shall be continuous and routed in the shortest, straight-line path possible. AC and DC ground detectors shall be provided for each train control room and house, and the sensitivity shall be sufficient to detect a ground leakage resistance of 0 to 2,000 ohms for AC ground and 0 to 10,000 ohms for DC ground.

22.7.2. Trackside PTC Equipment and Structures

Grounding of wayside equipment and metallic structures, including houses and wayside cases, shall be localized as much as practical with ground rods driven into the earth as close to the equipment/structure as possible. Where the structure design prevents the use of ground rods, grounding plates and grounding conductor (as detailed above for the aerial structures, retained fill, trenches, and tunnels) to which the signal equipment shall be grounded, shall be included in the Infrastructure design. See Section 22.3 and 22.5 for further details of facilities, buildings and structure grounding requirements.

The ground resistance shall not exceed 15 ohms as measured from equipment to ground where the ground rods are provided by the Systems contractor and 5 ohms from equipment to the grounding plate connection provided by the Civil Contractor.

The base of a ground-mounted signal mast or dwarf signal shall be bonded to the traction return system by direct connection to the neutral leads of an impedance bond adjacent to the signal. There shall be no other electrical connections between the signal mast and other structures or other rails or neutral leads unless specifically called for on the plan as part of an "A" point (see below).

Signal bridges or cantilever structures at a location that is not an "A" point (see below) shall not be electrically connected to any neutral leads or any portion of any track structure that is part of the signal system. These structures shall be bonded to the static wire.

22.7.3 Cross Bonding

In signaling systems using track circuits in which the block lengths are defined by insulated joints in the track, impedance bonds are employed to permit the traction return current in the rails to pass through a relatively low impedance on its way back to the substation, while at the same time presenting a very high impedance to the signal circuit. The connections to impedance bonds are configured in a variety of ways, as discussed below, and the bonds are usually installed at the insulated joints.

The preferred locations for all impedance bonds will be identified under the TP system design but must then be coordinated and confirmed by PTC system designer who shall undertake the block design. Once the locations have been confirmed, the Trackwork Contractor, who shall supply the joints, will install the insulated joints at the agreed locations. The ATC Contractor shall supply and install the bonds, and the OCS Contractor will supply and install the center tap bond connections and the exothermically welded rail tap connections. The ATC Contractor shall supply and install the track circuit connections.

<u>General Requirements</u>

Impedance Bond arrangements are of 5 different configurations:

- An "A" point is defined as a location where impedance bond neutral leads on all tracks are bonded together, and to one or more OCS support structures which are in turn bonded to the static wires

- An "A1" point is defined as a location where there are no insulated joints and the "Drain Bond" neutral leads on all tracks are bonded together, to the OCS support structures (which are bonded to the static wire), and in turn bonded directly to the Traction Power Substations, Switching Station and Paralleling Stations rail return bus.
- A "B" point is defined as a location where the impedance bonds neutral leads connect two tracks together, but are not connected to OCS support structures or the static wire.
- A "C" point is defined as a location with no cross bonding. The neutral leads of impedance bonds on either side of a pair of insulated joints on a track are tied together with no connections to adjacent tracks, OCS support structures or static wires.
- A drain bond is an impedance bond installed to connect the rails to traction power facilities, such as substations, switching stations, and paralleling stations, where no insulated joints exist in the tracks in the vicinity of the traction power facility. At such locations, the neutral leads of the drain bonds shall be connected directly to the traction power facility return bus. Drain bonds shall also be used at stations for connecting the platform counterpoise or grounding system to the rails where there is no adjacent "A" or "C" bond to which the platform grounds could be connected. Drain Bond locations on Signal Plans are sometimes referred to as "BC Points".

The purpose of cross-bond locations ("A" and "B" points) is to minimize step voltages on the rails to values that are less than the limits specified in Table 22-1. Cross-bond locations shall include a minimum of 2 track circuits between them and should, if practical, be located not less than 6,000 feet apart but not more than the permissible potentials will permit. The PTC system designer shall coordinate the cross-bonding locations with the TES designers.

Where cross-bonds are more than 6,000 feet apart:

- Distance between cross-bond locations shall be not less than 167 percent of the length of the longest track circuit, any portion of which lies between the cross-bond points.
- Conversely, the total length of any track circuit, any portion of which is between the cross-bond points, shall not exceed 60 percent of the distance between the cross-bond points.
- The ideal arrangement shall be two equal length track circuits between cross-bond points, each 50 percent of the total distance between them.

Where the cross-bonds are up to a maximum of 6,000 feet apart:

- There shall be a minimum of 3 track circuits between the "A" and "B" point cross-bond locations.
- Distance between cross-bond locations shall be not less than 250 percent of the length of the longest track circuit, any portion of which lies between the cross-bond points.
- Conversely, the total length of any track circuit, any portion of which is between the cross-bond points, shall not exceed 40 percent of the distance between the cross-bond points.
- The ideal arrangement would be three equal length track circuits between cross-bond points, each 33.33 percent of the total distance between them. Total distance shall be as close to 6,000 feet as possible.
- In no case will a distance of less than 3,000 feet between "A" point cross-bond locations be permitted.

The "percent ratio" shall be calculated for any given section between cross-bond locations as D(XB) divided by D(LTC), where D(XB) is the distance between cross-bond points defining the section and D(LTC) is the length of the longest track circuit in the section.

Where "drain" bonds constitute an "A" point at other than insulated joint locations, the "D(LTC)" shall be the total length of the longest track circuit in the section including any portion of that track circuit outside the limits of the section defined by the cross-bond points.

Cross-bonding at Interlockings

Cross-bonding shall be placed as close to interlocking crossovers as practical to reduce the possibility of flashover of insulated joints in crossovers. If possible, an "A" point shall be placed at one of the interlocking home signal locations at each interlocking. This shall be done consistent with these design criteria and the need to place an "A" point at each substation, switching station or paralleling station return bus location.

Only one impedance bond shall be provided at the fouling insulated joints on the turnout track, located on the side of the joints away from the switch points. The neutral leads on this impedance bond shall be tied to the neutral leads between the impedance bonds located at the adjacent insulated joints on the main or straight track.

If there are no insulated joints on the main or straight track within approximately 20 feet of the fouling insulated joints on the turnout track, then a second impedance bond may be used on the turnout track at the fouling insulated joints, located on the switch point side of these joints and the neutral leads of the two impedance bonds at these joints connected in the usual manner. In this case, the neutral leads of the impedance bonds on the turnout track must not be connected to the neutral leads on the main or straight track.

Cross-bonding at Single and Twin Single Bore Tunnels

Where an "A" point is required within a single bore tunnel, the neutral leads of the impedance bonds shall be connected to the static wire in that tunnel only. Where an "A" point is required within twin single bore tunnels that incorporate cross passage(s) between bores, cross-bonding between bores shall be accomplished by laying the cables in the cross-passage(s).

Connections to Platform Grounding Systems

Counterpoises for at-grade station platforms shall be connected to the rail through the neutral leads of an impedance bond at one end of the platform only. The preference is to connect to the neutral leads of an "A" point. If it is not practicable to attach to an "A" point, the counterpoise shall be connected to the neutral leads of a "C" point. If this is not practicable, a drain bond shall be installed. Each platform shall have an independent counterpoise and impedance bond.

The interconnection between the impedance bond neutral leads and the counterpoise conductor shall be an exothermic weld which shall be made in a handhole interface box.

Platforms located on aerial structures shall be grounded as identified above and shall be connected to the track through the neutral leads of an impedance bond at one end of the platform only, and with the same order of preference as detailed above. Each platform shall have an independent grounding system and impedance bond. If the impedance bonds used for this purpose are either "C" points or drain bonds, the location becomes a "B" point as the platform counterpoises on structures are attached to the structure and therefore both tracks will be connected together through the neutral leads of the impedance bonds.

22.8 Grounding and Bonding Protection Systems for the Communications System Equipment and Structures

22.8.1 General Requirements

Communications and electronic systems shall be grounded and bonded in accordance with the requirements specified in NFPA 70E, NFPA 75, ANSI/TIA/EIA-607, CEC, IEEE 1100 and ITU standards. The communications designer shall design a communications grounding system to have an impedance from device to ground per IEEE 1100.

The grounding methods for enclosures, chassis, panels, switch boxes, pull boxes, conduits, terminal boxes, and similar enclosures or structures shall be designed to provide proper terminations for equipment and cable shielding (as necessary) and to avoid conducted coupling, low impedance ground loops, noise, surges from adversely affecting system operation, and hazardous operating conditions—refer to the Electromagnetic Compatibility and Interference chapter for more details.

The AC grounding electrode system is the fundamental grounding element supporting the communications grounding system. The AC grounding electrode system design must be verified to provide a suitable ground resistance for all communications equipment it serves. The communications designer shall use the building structural steel as an additional bonding point for the communications grounding system. The impedance between the structural steel and the AC ground electrode system shall be compliant with IEEE Std. 142.

If the AC grounding electrode system does not supply compliant ground resistance, supplemental grounding electrodes shall be installed to lower ground resistance, and shall be connected to the AC grounding electrode system and the ground grid.

The communications grounding system serves to establish a common reference voltage for communications equipment cabinets, enclosures, equipment, and power supplies, and provide an intentional path for fault current to the AC grounding electrode system.

The components that make up the communications grounding system include:

- Supplemental grounding electrodes
- Bonding conductor for communications
- Telecommunications Bonding Backbone (TBB)
- TBB Interconnecting Bonding Conductor (TBBIBC)
- Telecommunications Grounding Busbar (TGB)
- Rack Grounding Busbar (RGB)

Design documents shall clearly articulate details and connectivity of the communications grounding system.

The communications designer shall design a separate communications-only or isolated ground system.

Bonding conductors shall be sized according to applicable standards and codes.

Bonding conductors run for distances less than 100 feet shall be minimum 6 AWG. For distances greater than 100 feet, the communications designer shall size bonding conductors using the more conservative requirements of either the NEC or the CEC.

22.8.2 Communication Equipment within Rooms at Stations and Facilities (located within a Shared PTC and Communications Room and/or Dedicated Communications Room)

See Section 22.5 for ground grid requirements for buildings.

When communications equipment and PTC equipment occupy a shared room, the designer shall coordinate the equipment and shield grounding between the two disciplines.

Telecommunications Bonding Backbone (TBB) within Stations and Facilities Communications room grounding busbars shall be connected together by means of the telecommunications bonding backbone, which shall provide for the interconnection of the grounding busbars, located in each communications room or closet throughout the building, to the telecommunications main grounding busbar.

The telecommunications bonding backbone route and cable size shall be planned to minimize length and eliminate splices.

Wherever two or more vertical telecommunications bonding backbones are used in a building, the grounding busbars shall be interconnected at the top of each riser and at every third floor with a telecommunications bonding backbone interconnecting bonding conductor in accordance with ANSI/TIA/EIA-607 and the CEC and NEC.

22.8.3 Grounding Busbars within Communications Rooms within Stations and Facilities.

A grounding busbar shall be provided in every communications room and within every shared PTC and communications room. An entrance facility shall be identified for each building where communications conduit and cable penetrates. The entrance facility shall be provided with a grounding busbar. The grounding busbar shall be located close to the AC ground electrode system. Where a panel board for telecommunications is located in the same room or space as the grounding busbar, that panel's ground bus or the enclosure shall be bonded to the grounding busbar.

In steel building structures, the telecommunications grounding busbar and telecommunications bonding backbone shall be bonded to the structural steel. The ground resistance between the structural steel and the AC grounding electrode system shall be compliant with IEEE Std. 142.

The communications grounding system in each room shall be bonded to the busbar in each communications room and communications closet. In communications rooms and closets, the busbar shall be bonded to the AC grounding electrode and the nearest structural steel member.

22.8.4 Communications Equipment and Structures

Provide a grounding busbar within all communications interface cabinets (CICs). Within CICs, the equipment grounding system shall bond equipment, rack rails, cabinets and cabinet doors to the telecommunications grounding busbar which shall be bonded to the incoming AC grounding electrode.

22.9 Grounding and Bonding Requirements for Facility Power Systems and Lighting Systems

See Section 22.5 for ground grid requirements.

A bare grounding electrode conductor shall be provided between the HV switchgear/transformer ground bus and the ground grid.

The secondary neutral of pad mounted medium and/or high voltage transformers shall be grounded. Additionally, the pad design shall include the following features:

- Ground grid in accordance the CEC, or power utility service requirements as applicable.
- The concrete support pad reinforcement steel shall be bonded to the ground grid.

Exterior transformers supplying interior service equipment shall have the neutral grounded at the transformer secondary and a grounding electrode shall be provided at the transformer.

In the case of separately derived systems (i.e., transformers downstream from service equipment) ground the secondary neutral at the transformer to the nearest component of the ground grid.

Lightning arresters on medium and high voltage equipment shall be connected to the equipment ground bus or ground rods as applicable.

For secondary switchgear, switchboards, and motor control centers, the following requirements shall apply:

- The equipment grounding conductors shall be connected to the ground bus in the enclosure with suitable pressure connectors.
- Metallic conduits, which terminate without mechanical connection to the housing, shall include grounding bushings and grounding conductor to the equipment ground bus.
- For service entrance equipment, the grounding electrode conductor, carried in the power supply conduit, shall be connected to the ground bus.

Ground the frames of motors larger than 25 hp by a ground conductor carried in power conduit.

Fixed electrical appliances and equipment shall be provided with a ground lug for termination of the equipment grounding conductor. Ground lugs shall be provided in each box and enclosure for equipment grounding conductor termination.

Panel boards shall contain a ground bus, bolted to the housing, with sufficient lugs to terminate the equipment grounding conductors.

Ground light fixtures to the equipment grounding conductor of the wiring system.

Receptacles shall not be grounded through their mounting screws. Ground with a jumper from the receptacle green ground terminal to the device box ground screw and the branch circuit equipment grounding conductor.

Feeder and branch AC power and lighting circuits shall have a separate insulated equipment grounding conductor.

Bond the equipment grounding conductor to each pullbox, junction box, outlet box, device box, cabinets, and other enclosures through which the conductor passes.

22.10 Grounding Requirements for Raceway, Cable Tray, Underground Ductbanks, and Structures

Metallic raceway and cable trays systems shall be bonded together to provide a continuous electrical ground path.

Metallic raceways shall be bonded to other raceway components using insulated grounding bushings. Grounding bushings shall be connected to the grounding system using conductors sized in compliance with the applicable code.

Connect each isolated metallic cable tray system or the entire cable tray system to the building grounding systems with a bare copper conductor in accordance with the CEC, NEC, and NEMA VE 1.

Provide an equipment ground conductor, sized in accordance with the CEC and NEC (but not less than 2 AWG for medium voltage power circuits) in each conduit of an underground ductbank that contains power cables.

Raceways for lighting and power feeders to motor, lighting, and receptacle loads shall contain a separate green insulated safety grounding conductor.

All normally-non-current-carrying conductive parts of manholes, handholes, pull boxes, splice boxes, metallic raceway, and/or cable tray systems shall be bonded and grounded. Provide at least one driven ground rod at each underground structure.

22.11 Cables

22.11.1 General

The metallic sheaths, armor or shields of power cables:

- Shall be electrically continuous through troughs, manholes, pull boxes, and splice boxes and any other cable carrying infrastructure.
- Shall be designed and routed in accordance with the requirements detailed in the Electromagnetic Compatibility and Interference chapter.

Conductor splice case grounding and bonding requirements shall comply with the manufacturer's recommendations and CEC and NEC. It shall be ensured that the touch voltages at the non-grounded end of the metallic sheaths, armor or shields of cables do not exceed the maximum permissible touch voltages specified in Table 22-1.

22.11.2 Signaling & Train Control System

The signal designer shall determine as part of its system design and its Electromagnetic Compatibility (EMC) plan, whether to utilize PTC cables with or without metallic shielding. Metallic messenger or duct shall not be used in any way that could cause an electrical interconnection between signals or signal structures and signal equipment housings.

22.11.3 Communications System

Bonding of shielded twisted-pair (STP) cables is necessary to mitigate the effects of unwanted noise signals (antenna effect) on communications cables and to avoid interference with overall network performance.

The shield of STP cables shall be bonded to the connecting hardware in accordance with the manufacturer's instructions. As appropriate, the connecting hardware at the cross-connect shall be bonded to the ground busbar in the PTC room or house, communications equipment shelter or termination room, or communications room. Grounding at the work area is usually accomplished through the equipment power connection. Shield connections at the work area are accomplished through an STP patch cord. At the work area end of the horizontal cabling, the voltage measured between the shield and the ground wire of the electrical outlet used to supply power to the workstation shall not exceed 1.0 Vrms. Telephone and public address cables at PTC rooms or houses, communications shelters or termination rooms, and communications rooms that originate from the field devices, shall require surge protection.

Bond telephone protector units to the grounding system with at least a No. 6 AWG ground conductor.

22.11.4 Facility Power System and Lighting System

The shields of medium voltage AC power cables shall be grounded at the facility power electrical rooms and/or yards in accordance with the requirements detailed in the Electromagnetic Compatibility and Interference chapter. The shields shall be electrically continuous through manholes, pull boxes, and splice boxes.

The safety grounding conductors for feeder circuits shall each be bonded at one end to the electrical room or yard ground bus and at the other end to the ground bus of a panelboard or a motor control center ground bus. Each branch circuit shall have a safety-insulated grounding conductor extended from the ground bus of the panelboard or motor control center to the device it is serving.

22.11.5 Cable Trough and Outside Plant

Provide an equipment ground conductor, sized in accordance with the CEC (but not less than 2 AWG for medium voltage power circuits), in each conduit of an underground ductbank that contains power cables.

All normally non-current-carrying conductive parts of manholes, handholes, pull boxes, splice boxes, metallic raceway, and/or cable tray systems shall be bonded and grounded.

The communications and signal designer shall coordinate with other disciplines and submit code compliant Outside Plant Cable (OSP) infrastructure bonding system.

22.12 Grounding and Bonding Requirements for Utilities

Non-railway pipes or cable shields should have no connection to the traction return and grounding systems. Metallic utility lines entering or passing through the Caltrain right-of-way shall be fitted with insulated joints to separate the external services and isolate them from the traction return and grounding systems.

Pipes or shielded cables to or from non-railway installations may transfer potentials that could be bridged by persons as step or touch voltages. Additionally, corrosion may be caused by potential differences, if different grounding systems are connected together. For these reasons non-railway grounding systems shall not be connected to railway systems.

Metallic sleeves or casings, installed to permit utility lines to cross the tracks (refer to the Utilities chapter) shall be grounded at one end only, with the grounding electrode having a resistance of 25 ohms or less.

Grounding and bonding for the electrical service shall be provided in accordance with the electric utility company's requirements.

Unless formally approved by the utility owner there shall be no connection between the grounding system and any utility (including water) outside the dielectric coupling which is used to isolate facilities from utilities outside the building line.

22.13 Lightning Protection

Each facility and exposed structure shall be provided with appropriate lightning protection measures, based on the incidence of strikes in the area local to each facility, which shall be grounded in accordance with the recommendations of the equipment manufacturer, CEC, NEC, NESC, GO 95, and NFPA 780 – Standard for the Installation of Lightning Protection Systems, as applicable.

22.14 Insulated Cables Carrying Feeds To The OCS Shall Be Protected With Surge Arresters

The OCS designer shall investigate the incidence of lightning storms on a project section-by-section basis and shall determine appropriate lightning protection measures based upon the incidence of lightning strikes in each area. A static wire shall be positioned at the top of OCS poles to afford protection to the OCS system against lighting strikes. If the cone of protection afforded from this position is insufficient, the static wire shall be mounted on an outrigger cantilever so that shield wire is more closely positioned above and affords protection for all of the OCS conductors. The static wire shall be insulated from the OCS poles in passenger station areas. Additional protection/mitigation measures, e.g., additional grounding conductors/grids, shall be provided as required.

Surge arresters and other circuit protection devices shall be provided as necessary to protect wayside PTC equipment from damage and false operation due to lightning. The surge arresters shall comply with AREMA Signal Manual, for lightning protection.

Trackside antenna towers (e.g. at PTC houses, communication equipment shelters, TPF, etc.) within the Caltrain right-of-way are specified to be 100 feet tall. Appropriate lightning protection measures shall be provided based on the incidence of strikes in the area local to each antenna tower and/or roof mounted antenna.

Reinforced concrete structures may not be able to take direct lightning strikes without damage. Exposed pre-stressed concrete structures shall be provided with lightning protection, especially in lightning prone areas.

The electrodes—ground rods or ground grids—used to ground lightning protection systems shall not be the same as those used for grounding of either the traction or facility electrical systems, but the electrodes from both systems must be bonded together.

END OF CHAPTER