California High-Speed Train Project

# TECHNICAL MEMORANDUM

## OCS Structural Requirements

## TM 3.2.2

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# System Level Technical and Integration Reviews

The purpose of the review is to ensure:

- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memorandums. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the System Level technical and integration review by any Subsystem must be approved by the Engineering Manager.

System Level Technical Reviews by Subsystem:

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| Systems: | NOT REQUIRED<br>Rick Schmedes | <br>Date |
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# ABSTRACT

The purpose of this technical memorandum is to review standards and best practices to provide criteria for the overhead contact system (OCS) structural requirements for the California High Speed Train Project to:

- Provide a general system description and define the general technical requirements of the OCS structural requirements
- Define the environmental requirements and climatic conditions applicable to the CHSTP overhead contact system
- Define the OCS general loading for structural calculations
- Define the OCS structural requirements for foundations, steel structures, and deflection requirements
- Define the structural requirements applicable for the execution of the design, construction, testing and commissioning of the overhead contact system.

Development of the design criteria for the Overhead Contact System will include review and assessment of, but not be limited to, the following:

- Existing FRA, State of California General Orders, NESC, IEEE, NFPA, ASTM, AISC, CBC, TSI, and EN guidelines where applicable
- Existing international standards, codes, best practices and guidelines used for existing High Speed Line Systems and applicable for the Overhead Contact System for applicability to the CHSTP.
- Other existing international standards, codes, best practices and guidelines applicable for the Overhead Contact System

The current design practices for high-speed overhead contact system presently in operation throughout the world are considered in the development of the Overhead Contact System for the CHST project.

# 1.0 INTRODUCTION

## 1.1 Purpose of Technical Memorandum

The purpose of the technical memorandum is to review standards and best practices to provide criteria for the overhead contact system structural requirements for the California High Speed Train Project to:

- Provide a general system description and define the general structural requirements of the overhead contact system
- Define the overhead contact system structural requirements for the California High Speed Train Project (CHSTP)

It will thus promote safe and efficient operations for high-speed rail train service on both segments of CHSTP alignment that are dedicated to very high speed and for those in shared use operation.

This memorandum presents data relating to the design, construction and testing of the overhead contact system structure that must be satisfied. Where available, it is based on present U.S. Federal and State Orders, guidelines and practices. Document searches were conducted to identify definitive criteria to be used for the CHSTP application and, in some cases, data were not available. Present practices for high speed railways were reviewed and used to define criteria for the CHST project that are incorporated in this memorandum.

It is anticipated that the design will be advanced consistent with applicable codes of practice, design guidelines and other information that define the CHSTP programmatic, operational, and performance requirements.

Following review, specific guidance in this technical memorandum will be excerpted for inclusion in the CHSTP Design Manual.

## 1.2 STATEMENT OF TECHNICAL ISSUE

The CHSTP overhead contact system is powered at high voltage (25kV). All structures are exposed to wind forces throughout their whole life and, in tangent track situations, are loaded with a higher ratio of wind load than permanent load. A high risk factor shall be accorded to wind loading on OCS poles and structures due to the serious risk to operational availability in the event of structural failure. Ensuring no structure failure under broken wire or feeder contingencies is an important technical issue when planning high speed train operation, but cannot be realized without having carefully defined the structural requirements for the overhead contact system, and its combined loading conditions.

In addition to the issue of structural failure, other technical items related to structural deflection must be defined for the design, construction and testing to ensure that structural deflections do not cause any de-wirement and do not interfere with the overhead contact system operation. The correctly designed system will thus meet the requirements of safe operation with maximum reliability, availability, and maintainability.

## 1.3 GENERAL INFORMATION

### 1.3.1 Definition of Terms

The following technical terms and acronyms used in this document have specific connotations with regard to California High Speed Train system.

Aerodynamic force - Additional vertical force applied to the pantograph as a result of air flow around the pantograph assembly.

Ambient temperature - Outdoor air temperature at any given altitude.

Catenary - An assembly of overhead wires consisting of, at a minimum, a messenger wire supporting vertical hangers that support a solid contact wire which is the contact interface with operating electric train pantographs.

Contact force - The vertical force applied by the pantograph to the overhead contact line. The contact force is the sum of forces for all contact points of one pantograph.

Contact point - Point of mechanical contact between a contact strip and a contact wire.

Contact Wire - A solid overhead electrical conductor of an Overhead Contact System with which the pantograph of electric trains makes contact to collect the electrical current.

Contact Wire Height - Height of the underside of the contact wire above top of rail level when not uplifted by the pantograph of an electric train.

Dead Load - Static Load that is relatively constant throughout the life of a structure.

Headspan - An across-track support arrangement comprising two or more wires that provide support for one or more OCS equipments. Headspans can be attached to two separated poles or to wayside buildings or other fixed structures.

Live Load - Load that varies due to dynamic factors within the normal operating cycle, but excluding seismic effects.

Non-operating condition - The conditions under which the trains will not be permitted to maintain continuous operation, and revenue service will cease.

Operating condition - The conditions under which the trains will be permitted to maintain continuous operation, and for which the OCS shall provide full, uninterrupted and acceptable performance.

Overhead Contact System (OCS) - Also called Overhead Catenary system or Overhead Contact Line. Part of the traction power electrification system, comprising overhead wires including the contact wire and messenger wire placed above the upper limit of the rail vehicle gauge, but also including auxiliary wires (aerial feeder and aerial ground wires), supports, foundations, wire terminations, balance weight arrangements, electrical switches and isolators, and other equipment and

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| | assemblies. It supplies electric energy, coming from a traction power substation, to non self-powered rail vehicles operating beneath the overhead wires, through roof mounted current collection equipment,. |
| Pantograph - | Device consisting of spring-loaded hinged arms fitted to the roof of a train that collects current from the contact wire of an overhead contact system. |
| Portal Structure - | An OCS structure consisting of a crossbeam or truss supported by two separated poles placed on either side of multiple tracks to support the OCS conductors. The OCS supports are attached to the beam or truss to support the OCS. |
| ROW - | Right of way. |
| Shared Use Corridor - | Segment along the CHSTP alignment where high speed trains share ROW with other passenger railroads, i.e. Caltrain, Metrolink, and Amtrak |
| Shared Use Track - | Segment along the CHSTP alignment where high speed trains operate with other passenger railroads, i.e. Caltrain, on the same tracks. |
| Steady arm - | A lightly loaded registration arm that serves to steady the contact wire from lateral displacement. |
| Trolley Wire - | Alternative term for contact wire used for single wire OCS. See Contact wire and Overhead Contact System. |

Tension Length (or Tension section) - Length of a catenary section between its two termination points.

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| Wire Load - | The loads that are generated from the tensioned wires. |

Acronyms

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| AAR | Association of American Railroads |
| ACI | American Concrete Institute |
| AISC | American Institute of Steel Construction |
| ANSI | American National Standards Institute |
| AREMA | American Railway Engineering and Maintenance of Way Association |
| ASCE | American Society of Civil Engineers |
| AWS | American Welding Society |
| Caltrans | California Department of Transportation |
| CBC | California Building Code |
| CFR | Code of Federal Regulations |
| CHST | California High-Speed Train |
| CHSTP | California High-Speed Train Project |
| CPUC | California Public Utilities Commission |
| EN | European Standards |
| FRA | Federal Railroad Administration |
| G.O. | General Order |
| IEEE | Institute of Electrical and Electronics Engineers |
| NESC | National Electrical Safety Code |
| PUC | Public Utilities Commission of the State of California |
| SCRRA | Southern California Railroad Authority |
| SNCF | Société Nationale des Chemins de fer Français (French National Railway Company) |
| TSI | Technical Specification for Interoperability of European High-Speed Lines |
| UIC | International Union of Railways (Union Internationale des Chemins de Fer) |

### 1.3.2 Units

The California High-Speed Train Project is based on U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the United States, and are also known in the U.S. as "English" or "Imperial" units. In order to avoid any confusion, all formal references to units of measure should be made in terms of U.S. Customary Units.

# 2.0 DEFINITION OF TECHNICAL TOPICS

## 2.1 General

Design criteria and other specific requirements related to OCS structural requirements must be defined for the design, procurement, construction design, and construction and testing of the CHSTP to ensure that the overhead contact system and OCS structures will satisfactorily ensure safe operation, and maximum reliability, availability, maintainability and safety at maximum envisaged operating speeds.

## 2.2 LAWS, CODES AND STANDARDS

### 2.2.2 NORTH AMERICAN RECOMMENDED PRACTICE AND LEGAL REQUIREMENTS IN CALIFORNIA

AREMA Manual

The primary orientation of the American Railway Engineering and Maintenance of Way Association (AREMA Manual) is to provide guidance in the engineering of railroads moving freight at speeds up to 80 mph (FRA Class 5 track) and passenger trains at speeds up to 90 mph with the exception of the still incomplete Chapter 17, High-Speed Rail Systems.

The material presented in the AREMA Manual varies considerably in level of detail and applicability to the CHSTP. Therefore, a reference to the AREMA Manual without a more specific designation of applicable chapter and section is not sufficient to describe any requirement.

When using the AREMA Manual, the statement at the beginning of each chapter will assist in understanding the scope, intent, and limitations of this document.

> "*The material in this and other chapters in the AREMA Manual for Railway Engineering is published as recommended practice to railroads and others concerned with the engineering, design and construction of railroad fixed properties (except signals and communications), and allied services and facilities. For the purpose of this Manual, RECOMMENDED PRACTICE is defined as a material, device, design, plan, specification, principle or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency and economy in the location, construction operation or maintenance of railways. It is not intended to imply that other practices may not be equally acceptable.*"

Legal requirements in California

The requirements of California PUC General Orders shall govern regardless of lesser dimensions in other standards or guidelines. Legal minimum clearances around railroad tracks in California are defined in PUC GO 26-D. It has determined in coordination meetings with CPUC that the legal rules for Overhead Electric Line Construction as defined in PUC GO 95 are not applicable to 25 kV electrified overhead contact systems and therefore the CHSTP OCS design. CHSTP is developing proposed language for a new regulation governing 25 kV railroad electrification, and will petition to CPUC to adopt this new regulation as a new General Order under Order Instituting Rulemaking process.

### 2.2.3 CHSTP DESIGN CRITERIA FOR OCS STRUCTURAL REQUIREMENTS

Design criteria for the CHSTP are under development. When completed, a CHSTP Design Manual will present design standards specifically for the construction and operation of high-speed railways based on international best practices and present US Federal and State standards and codes. Initial high-speed rail design criteria will be issued in technical memoranda that provide guidance and procedures to advance the design of project specific elements. Criteria for design elements not specific to HSR operations will be governed by existing applicable standards, laws and codes.

The development of the CHSTP design criteria applicable to the OCS structural requirements are based on a review and assessment of available information, including the following:

- AREMA Manual
- California Public Utilities Commission General Orders 26-D
- Amtrak guidelines and present practices
- Federal and State Orders guidelines and present practices
- Caltrain Design Criteria (April 15, 2007)
- Energy Technical Specification for Interoperability of European High Speed Rail System
- EN 50119:2001
- Existing ASCE, AWS, ANSI, IEEE and NESC standards and guidelines where applicable
- Other existing international standards, codes, best practices and guidelines used for existing High-Speed Line Systems and applicable to the OCS structural requirements for application to the CHSTP.

Initial high-speed rail design criteria will be issued in technical memoranda that provide guidance and procedures to advance the preliminary engineering (15% and 30% design) of the project. When completed, a Design Manual will present design standards and criteria specifically for the design, construction and operation of the CHSTP high-speed railway based on international best practices.

The CHSTP design standards and guidelines may differ from local jurisdictions' codes and standards. In the case of differing values, conflicts in the various requirements for design, or discrepancies in application of the design guidelines, the standard followed shall be that which results in the highest level of satisfaction for all requirements or that is deemed to be the most appropriate by the California High-Speed Rail Authority. The standard shall be followed as required for securing regulatory approval.

# 3.0 ASSESSMENT / ANALYSIS

## 3.1 GENERAL

Structural requirements applicable to overhead contact systems are mainly based on American standards or guidelines applicable to the CHSTP Overhead Contact System and were collected along with the CHSTP characteristics and design criteria that are applicable to sections of the CHSTP dedicated to very high speed operation only and to sections of the CHSTP that are shared use corridors for both high-speed trains and conventional passenger trains. Based on those data, the following OCS structural requirements are considered as guiding criteria for the overhead contact system of the CHSTP.

## 3.2 ENVIRONMENTAL CONDITIONS FOR OCS

The environmental conditions applicable to the CHSTP OCS are described in a separate document, namely the ''OCS Requirements'' Technical Memorandum. This section addresses the additional conditions for further assessments.

The design of the OCS shall be based on technical, economical, and operational requirements, as well as maintenance requirements, and on the local climatic conditions. Designer shall ensure that the pantograph size range is considered and satisfied by the pantograph envelope and pantograph security. The OCS shall also accommodate the physical characteristics of the car and the performance requirements of the propulsion systems associated with the car, i.e. clearance envelopes, propulsion power supply voltage, etc.

The OCS shall be designed for multiple pantograph operation without causing excessive oscillation of the OCS or pantograph bouncing or arcing.

The current requirements of the AREMA "Manual for Railway Engineering," Chapter 33, the NESC and California PUC GO standards shall be used for the development of the OCS design. The local climatic conditions shall be assessed to define various climatic combinations. Prescribed/standard values for snow/ice shall usually be derived from (national) standards and regulations per region. Each combination shall be classified as either an "operating condition" or a "non-operating condition" for the OCS.

The operating conditions are defined as those under which the trains will be permitted to maintain continuous operation, and for which the OCS shall provide full, uninterrupted and acceptable performance. The non-operating conditions are defined as those under which the trains will not be permitted to maintain continuous operation and revenue service will cease.

These criteria assume that train operations will cease when wind speeds of 60 mph or higher are predicted. In no situation shall the contact wire lateral deviation cause any dewirement. The structural integrity and safety of the OCS design shall consider this extreme "non-operating" condition. In addition, the Caltrans extreme design condition, which also represents a "non-operating" condition, of a 100 mph wind plus 10% gust allowance at normal temperature shall be assessed.

Acceptable performance of the OCS shall be defined as being satisfactory for operation of revenue service only under the specified operating conditions.

The combinations of climatic conditions, as shown on the NESC Rule 25, shall be considered. In addition, the local extreme climatic combination, and the Caltrans Extreme Climatic Condition shall also be assessed

The OCS conductor wire temperature might reach 167 degree F due to the effects of ambient temperature, plus solar and resistive heating. Solar radiation shall be taken into account in accordance with annex B of EN50119:2001. OCS Designer shall evaluate the recorded temperature range, cantilever swing, OCS pole height, tension length, balance weight movement range, maximum allowable contact wire displacement, wire breaking strength, allowable along track movement, contact loss criteria, and pantograph security in determining the auto-tensioning temperature range.

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. For insulation and corrosion resistance reasons, the degree of pollution shall be confirmed according to the information given in Table A.1 of EN 50119:2001.

## 3.3 GENERAL OVERHEAD LINE LOADING

The loading assumptions to be applied in the design of all overhead wires and support structures shall conform to the more onerous values derived from NESC Section 25 or CPUC GO standards. The strength requirements shall conform to those specified in NESC Rule 26.

Where a structure is designed in accordance with a recognized code other than the NESC standards, the design shall ensure that all OCS safety factors meet or exceed the strength requirements for Grade B construction as specified in NESC standards. The permissible tensile loading of the wires and ropes shall consider the weighted parameters which include maximum temperature, allowable contact wire wear, wind and ice loads, tensioning accuracy and efficiency , termination fittings, welded or soldered joints, and conductor creep if applicable. The safety factor with allowable worn shall be no less than 2.0.

The general design loads include dead load, live load, wind load, and earthquake load. For foundation design buoyancy load might need to be considered if applicable. The seismic design shall ensure no collapse, safe performance, and operability. For seismic damage analysis and earthquake specific magnitude, refer to TM 2.10.4 Interim Seismic Design for detail.

In addition to the load condition indicated in NESC, the 100 mph wind plus 10% gust allowance shall be evaluated to prove no failure, and designer shall further evaluate the local extreme climate condition and adjust the load combinations for worst case loads. Refer to TM 2.3.2 for wind pressure on OCS poles due to slipstream effects caused by the proximity to HS trains with train speed in excess of 225 mph.

The $k_Z$ (Velocity pressure exposure coefficient) and $G_{RF}$ (Gust response factor) as indicated in NESC Rule 250C1) shall be calculated in accordance with the latest version of ASCE/SEI 7. The allowance for a one-third increase in allowable stress for wind combined loading shall be waived.

## 3.4 FOUNDATION REQUIREMENTS

The design of all OCS foundations, including cast-in-place concrete foundations, driven pile foundations, and direct embedment poles, shall be in accordance with the established civil and structural engineering practices, ASTM, AISC, and ACI standards, other applicable codes, and proven foundation engineering and anchoring methods. The foundation shall be designed in a manner to minimize the types and sizes for simplifying the constructability, to avoid disturbing existing adjacent structures, to provide flexibility for pole rake adjustment, and to minimize future maintenance costs. Where barrier issues, underground obstruction issues, or existing/new structure conflicts preclude the use of pier foundations or driven pile foundations, and the conflicts cannot be avoided by relocating the poles and foundations, designer shall design special foundations within CHSTP ROW to clear these conflicts or attach the poles, portal brackets, headspans or cantilevers to existing structures with the approval from the owner/designer of the existing/new structures.

The foundations shall be capable of meeting the structural loading requirements. The foundations shall be designed for each separate location, the structural dimensions being dependent on:

1. Loads on the poles due to the OCS, feeder cables, tensioning equipment, insulators, mid-point anchor ties, and all other necessary equipment
2. Wind loads on the poles and associated OCS equipment
3. Condition of the ground
4. Earthquake loads
5. The requirements of operation at the applicable speed.

In all cases, the foundation shall be designed to exceed the maximum design capability of the pole or structure being supported by the foundation by not less than 25% to ensure the foundation will not experience failure under the specified operating and non-operating conditions. The overturning moment shall not exceed 85% of the stability moment. In the case of calculations for supporting structures embedded in or attached to the faces of rock or masonry, the bond between the support and the rock or masonry shall be able to withstand an effort not less than 1.5 times the load applied to the structure.

All foundations and anchors shall be capable of handling the imposed construction loads during erection and withstanding a broken-wire failure condition, including breakage of both the static wire and parallel feeder conductor in any one span, without exhibiting major, catastrophic foundation damage. The viaduct structure designer shall design the viaduct in a manner such that the OCS pole locations on the viaduct are flexible along track and can be determined as part of detailed design. The strength of the structure shall take into consideration broken-wire conditions. In the event of breakage of one or more of the OCS wires, the intact part of the OCS will transmit an impact load to the viaduct structure via the poles. For design purposes, this load shall be taken as the sum of the tensions in the contact wire and messenger wire (assumed sum to be 13,300lb) per track acting in the direction of the intact part of the OCS wires. Two sets of OCS wires shall be assumed to break simultaneously. Except for direct embedment poles, the foundation height should be level with the top of high rail. The design of OCS pole foundations in station platforms shall be coordinated with on-going station design and with the approval of CHSTP. Where the OCS pole foundations in platforms are not recessed, pole base covers shall be provided. Special foundation heights shall not be precluded for those in cuttings or on embankments.

Existing geotechnical conditions shall be established by reviewing the existing soil data, local field testing, sampling and soils investigations. For geotechnical design, refer to TM 2.9.10 Geotechnical Analysis and Engineering Design Criteria Guidelines. Information suitable for the design of foundations 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 CHSTP ROW. These investigations shall also identify the sand and rock types encountered. 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 pole foundation locations shall be designed in a manner to avoid conflicts with existing or planned overhead or underground obstructions. For existing revenue service locations, the foundation shall be constructed in a manner not to disturb the existing tracks under revenue service.

## 3.5 STEEL STRUCTURE REQUIREMENTS

In double-track sections, the OCS poles shall be located outside the tracks with cantilevers for support of the OCS. It is desirable to avoid property take issues or station platforms. For multi track areas, where independent OCS poles cannot be installed between tracks, portal structures using drop tubes that will permit maintaining mechanical independence of the equipment related to individual tracks are to be designed with respect to overall aesthetics of the complete OCS. However, in shared use corridors and other sections with speed no more than 125mph, headspan arrangements may be used if considerations dictate.

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. Poles shall be designed as free-standing structures with flexibility for rake adjustment, except for poles carrying wire terminations, which shall be back-guyed, typically in the along track direction. For balance weight poles, the balance weight shall be placed outside the pole when separate weights are used for each wire. For poles in passenger stations or within any urban design area, the 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, catastrophic damage. 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 in passenger stations, within any urban design area, or in other special circumstances.
2. The design of bolted steelwork connections shall conform to AISC requirements and shall specify materials and methods in accordance with ASTM standards.
3. Anchor bolts shall be galvanized.
4. The design of structural and fabrication welding shall conform to the AWS, Standard D.1.1, “Structural Welding Code.”
5. Any required painting shall be specified to conform to the Steel Structure Painting Council, “Steel Structure Painting Manual,” Volumes 1 and 2.
6. 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.

Poles on station platforms shall be placed in a manner that minimizes the visual impact and passenger pass-by obstruction, and shall be integrated with platform architecture design. Where a counterpoise grounding method is used within a railroad passenger station, the aerial static wire shall be electrically isolated from the OCS structures and components connected thereto.

## 3.6 STRUCTURAL DEFLECTION REQUIREMENTS

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 will prejudice acceptable tracking and performance of the pantograph current collector.

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 purpose of structural design, this live loading is to 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 pole shall not intrude into the pantograph or vehicle envelope under any circumstances. The load factors indicated in NESC Rule 253 shall not be applied in the calculation of pole deflection.

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 or headspans, 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.

# 4.0 SUMMARY AND RECOMMENDATIONS

In both the above grade and below grade sections, steel OCS support structures and miscellaneous steel OCS support brackets are typically to be galvanized, and are to be designed and manufactured to the relevant steel standards.

Where the OCS is closely supported, multiple cantilevers may be attached to a single structure, in which case the applied loads shall not cause twisting of the structure by more than five (5) degrees.

The OCS supporting structures shall be calculated in accordance with relevant American standards (NESC, ASCE, ANSI) and, in addition, the maximum OCS pole deflection across track, including wind loading, is not to exceed two (2) inches at contact wire level.

For multi-track areas when independent OCS poles cannot be installed between tracks, portal structures using drop tubes that will permit maintaining mechanical independence of the equipment related to individual tracks are to be designed with respect to overall aesthetics of the complete OCS. Such portal structures will, for example, shall be used at crossovers and intermediate passenger stations where single OCS poles cannot be installed. Please refer to the CHSTP OCS Standard Drawings ref. OCS 004 for very high speed and OCS 014 for speeds up to 125 mph. However, in shared use corridors or other sections with speed up to 125mph, headspan arrangements (OCS Standard Drawing ref. OCS 020) may be used if considerations dictate.

In tunnels and cut and cover sections, or for wall fixings, supports shall be attached using either C-channels or anchor expansion bolts of the undercut type. Should structures need to be attached to the wall of tunnels, bridges, or to open cut walls, this is to be achieved by bolted connections suitable for the loading conditions and the wall material. In order to reduce the risk of drilling into reinforcement bars, specialized equipment shall be used to locate the reinforcing bars before drilling and the minimum distance from a reinforcing bar to the drilled hole shall be two (2) inches.

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

Each and every OCS support location shall be individually numbered for ease of identification on site. Structure number plates shall be fitted to the structure at a height of 6 ft-6 in approximately above rail level. For supports located in tunnels or cut and cover sections, the number plate shall be attached to the wall using suitable fixings.

# 5.0 SOURCE INFORMATION AND REFERENCES

- Energy Technical Specification for Interoperability of European High Speed Rail System
- CHSTP Basis of Design Policy – California High Speed Rail Program – Jan 08
- Technical Memorandum TM 1.1.10 Structure Gauge
- Technical Memorandum TM 3.2.3.3 Pantograph Clearance Envelopes
- California Public Utilities Commission General Order 26-D
- National Electrical Safety Code
- International Building Code
- EN 50119:2001
- UIC 606-1 OR
- The Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA Manual)

# 6.0 DESIGN CRITERIA MANUAL

- The OCS supporting structures shall be calculated in accordance with relevant American standards (NSCE, ASCE, ANSI, AISC, ACI).

- The loading assumptions and strength requirements shall meet or exceed the requirements of NESC standards, as qualified in this Technical Memorandum.

- The general design loads include dead load, live load, wind load, and earthquake load. For foundation design buoyancy load might need to be considered if applicable. The seismic design shall ensure no collapse, safe performance, and operability. For seismic damage analysis and earthquake specific magnitude, refer to TM 2.10.4 Interim Seismic Design for detail.

- In addition to the load condition indicated in NESC, the 100 mph wind plus 10% gust allowance shall be evaluated to prove no failure, and designer shall further evaluate the local extreme climate condition and adjust the load combinations for worst case loads. Refer to TM 2.3.2 for wind pressure on OCS poles due to slipstream effects caused by the proximity to HS trains with train speed in excess of 225 mph.

- The $k_Z$ (Velocity pressure exposure coefficient) and $G_{RF}$ (Gust response factor) as indicated in NESC Rule 250C1) shall be calculated in accordance with the latest version of ASCE/SEI 7. The allowance for a one-third increase in allowable stress for wind combined loading shall be waived. Designer shall further evaluate the local extreme climate condition and adjust the load combinations for worst case loads.

- 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.

- The foundations shall be capable of meeting the structural loading requirements. The foundations shall be designed for each separate location, the structural dimensions being dependent on:
  1. Loads on the poles due to the OCS, feeder cables, tensioning equipment, insulators, mid-point anchor ties, and all other necessary equipment
  2. Wind loads on the poles and associated OCS equipment
  3. Condition of the ground
  4. Earthquake loads
  5. The requirements of operation at the applicable speed.

- All foundation design shall be in accordance with the established civil and structural engineering practices, ASTM, AISC, and ACI standards, other applicable codes, and proven foundation engineering and anchoring methods.

- The OCS foundations 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 costs.

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

- All foundations and anchors shall be capable of handling the imposed construction loads during erection and withstanding a broken-wire failure condition, including breakage of both the static wire and parallel feeder conductor in any one span, without exhibiting major, catastrophic foundation damage.

- The viaduct structure designer shall design the viaduct in a manner such that the OCS pole locations on the viaduct are flexible along track and can be determined as part of detailed design. The strength of the structure shall take into consideration broken-wire conditions. In the event of breakage of one or more of the OCS wires, the intact part of the OCS will transmit an impact load to the viaduct structure via the poles. For design purposes, this load shall be taken as the sum of the tensions in the contact wire and messenger wire (assumed sum to be 13,300lb) per track acting in the direction of the intact part of the OCS wires. Two set of OCS wires shall be assumed to break simultaneously.

- 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 pole foundation locations shall be designed in a manner that avoids conflicts with existing or planned overhead or underground obstructions. For existing revenue service locations, the foundation shall be constructed in a manner not to disturb the existing tracks under revenue service.

- The design of all OCS steel structures, poles and supports shall conform to the AISC, including relevant seismic requirements.

- 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.

- 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, catastrophic damage.

- 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.

- 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 poles shall not be precluded for poles in passenger stations, within any urban design area, or in other special circumstances.

- The design of bolted steelwork connections shall conform to AISC requirements and shall specify materials and methods in accordance with ASTM standards.

- Anchor bolts shall be galvanized.

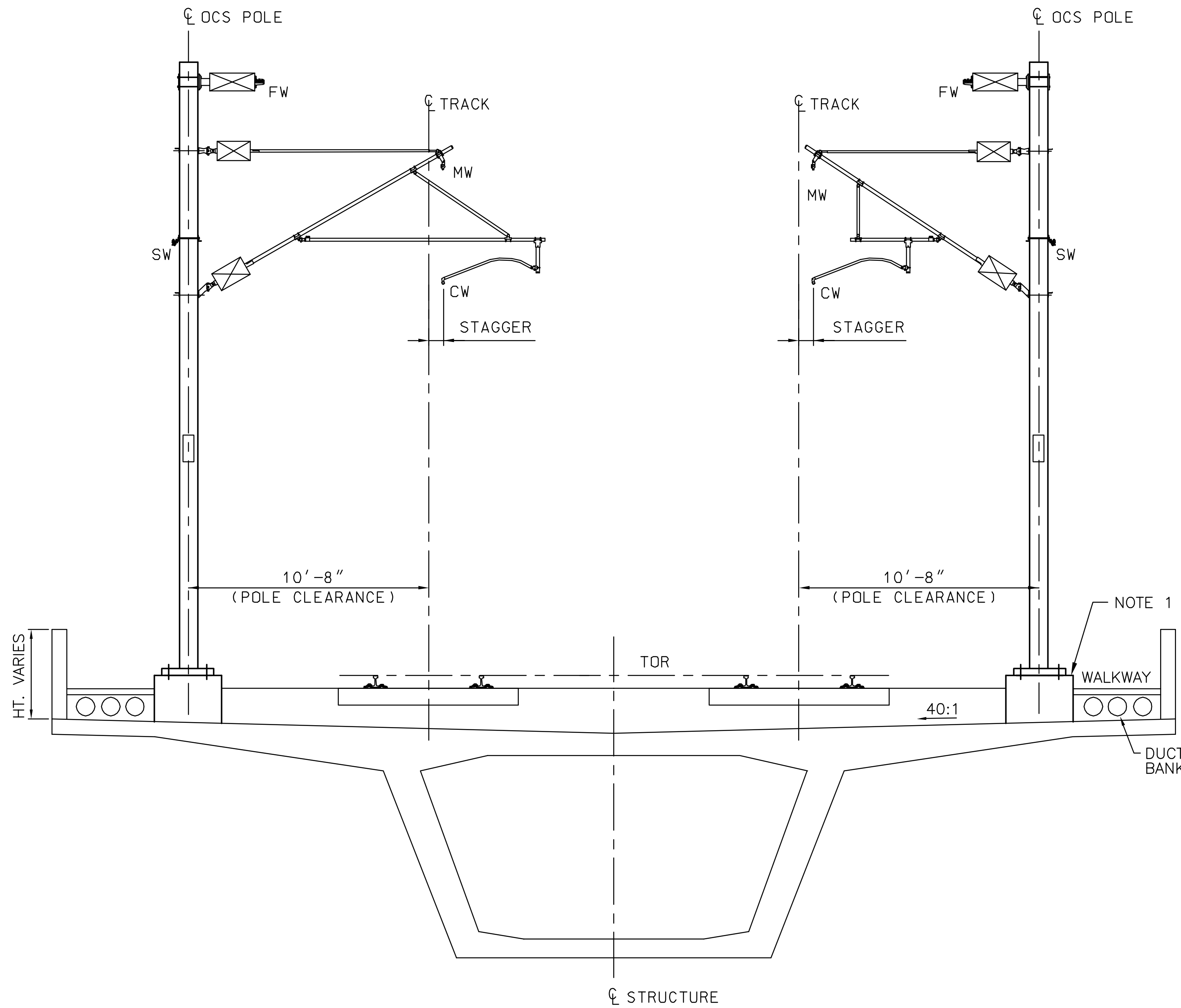
- The design of structural and fabrication welding shall conform to the AWS, Standard D.1.1, “Structural Welding Code.”

- Any required painting shall be specified to conform to the Steel Structure Painting Council, “Steel Structure Painting Manual,” Volumes 1 and 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.

- Poles in station platforms shall be placed in a manner that minimizes the visual impact and passenger pass-by obstruction, and shall be integrated with platform architecture design. Where a counterpoise grounding method is used within a railroad passenger station, the aerial static wire shall be electrically isolated from the OCS structures and components connected thereto.

- 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 will prejudice acceptable tracking and performance of the pantograph current collector.
- 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 purpose of structural design, this live loading is to 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.




**TYPICAL OCS SUPPORT STRUCTURE**
**TANGENT TRACK ON VIADUCT**

LEGEND:

| | |
|---|---|
| FW | NEGATIVE FEEDER WIRE |
| SW | STATIC WIRE |
| MW | MESSENGER WIRE |
| CW | CONTACT WIRE |
| SE | TRACK SUPERELEVATION |
| HRL | HIGH RAIL LEVEL |
| ℄ | CENTERLINE |
| TOR | TOP OF RAIL |

NOTE:

1. OCS POLE LOCATIONS SHALL BE DETERMINED BY FINAL SYSTEM DESIGNER. BRIDGE STRUCTURE SHALL BE DESIGN TO TAKE THE OCS LOAD INCLUDING BROKEN WIRE WIRE CONDITION.

$FILE$ $TIME$ $DATE$ $USER$

| REV | DATE | BY | CHK | APP | DESCRIPTION |
|---|---|---|---|---|---|

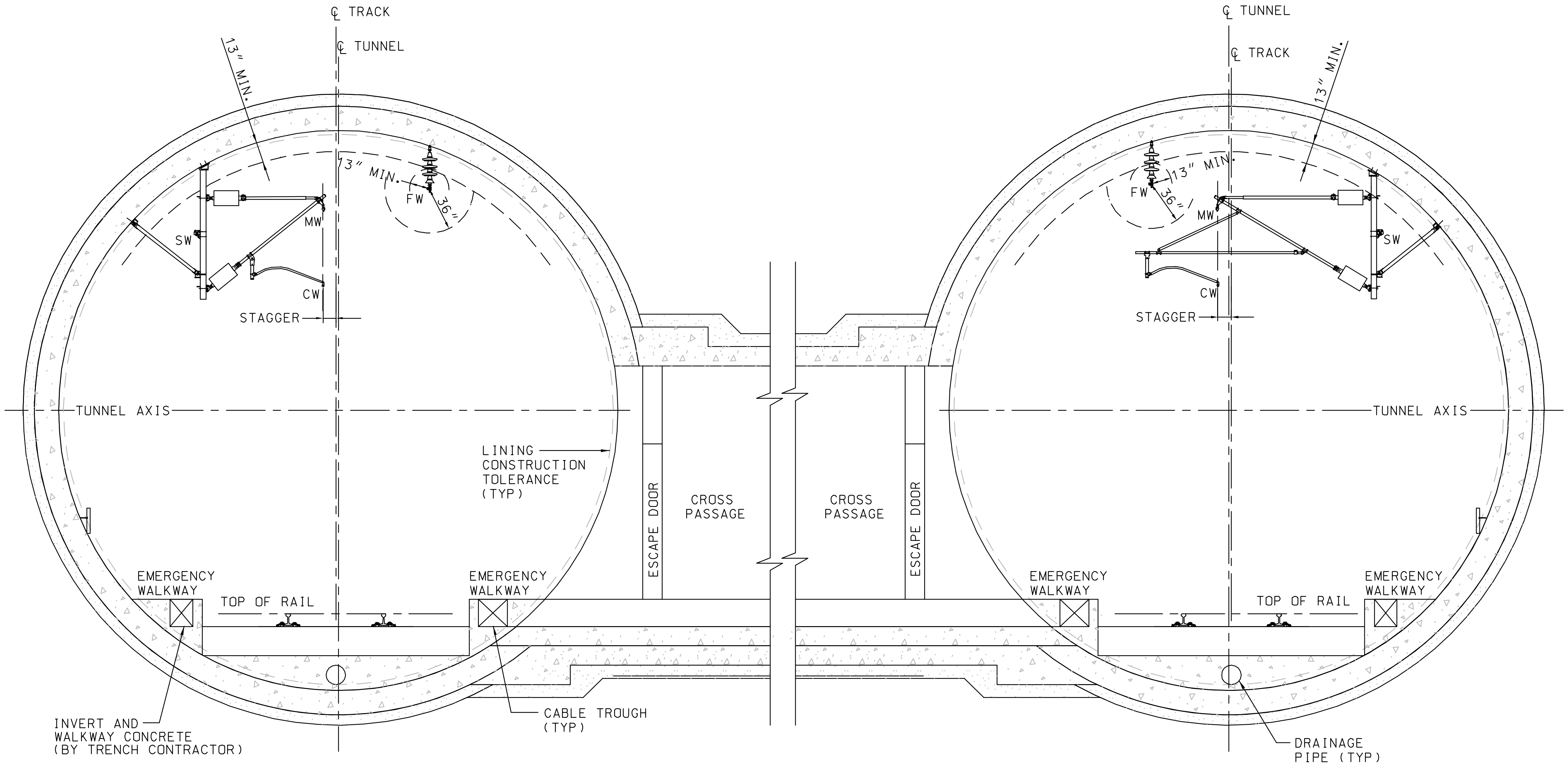
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE 11-30-09

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS SUPPORT STRUCTURE
ON VIADUCT – TANGENT TRACKS

CONTRACT NO.
DRAWING NO. TM 3.2.2-A
SCALE NTS
SHEET NO.




LEGEND:

| | |
|---|---|
| FW | NEGATIVE FEEDER WIRE |
| SW | STATIC WIRE |
| MW | MESSENGER WIRE |
| CW | CONTACT WIRE |
| SE | TRACK SUPERELEVATION |
| HRL | HIGH RAIL LEVEL |
| CL | CENTERLINE |
| TOR | TOP OF RAIL |

CIRCULAR TUNNEL - TANGENT TRACK

$USER$ $DATE$ $TIME$ $FILE$

| REV | DATE | BY | CHK | APP | DESCRIPTION |
|---|---|---|---|---|---|

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE 11-30-09

PARSONS BRINCKERHOFF

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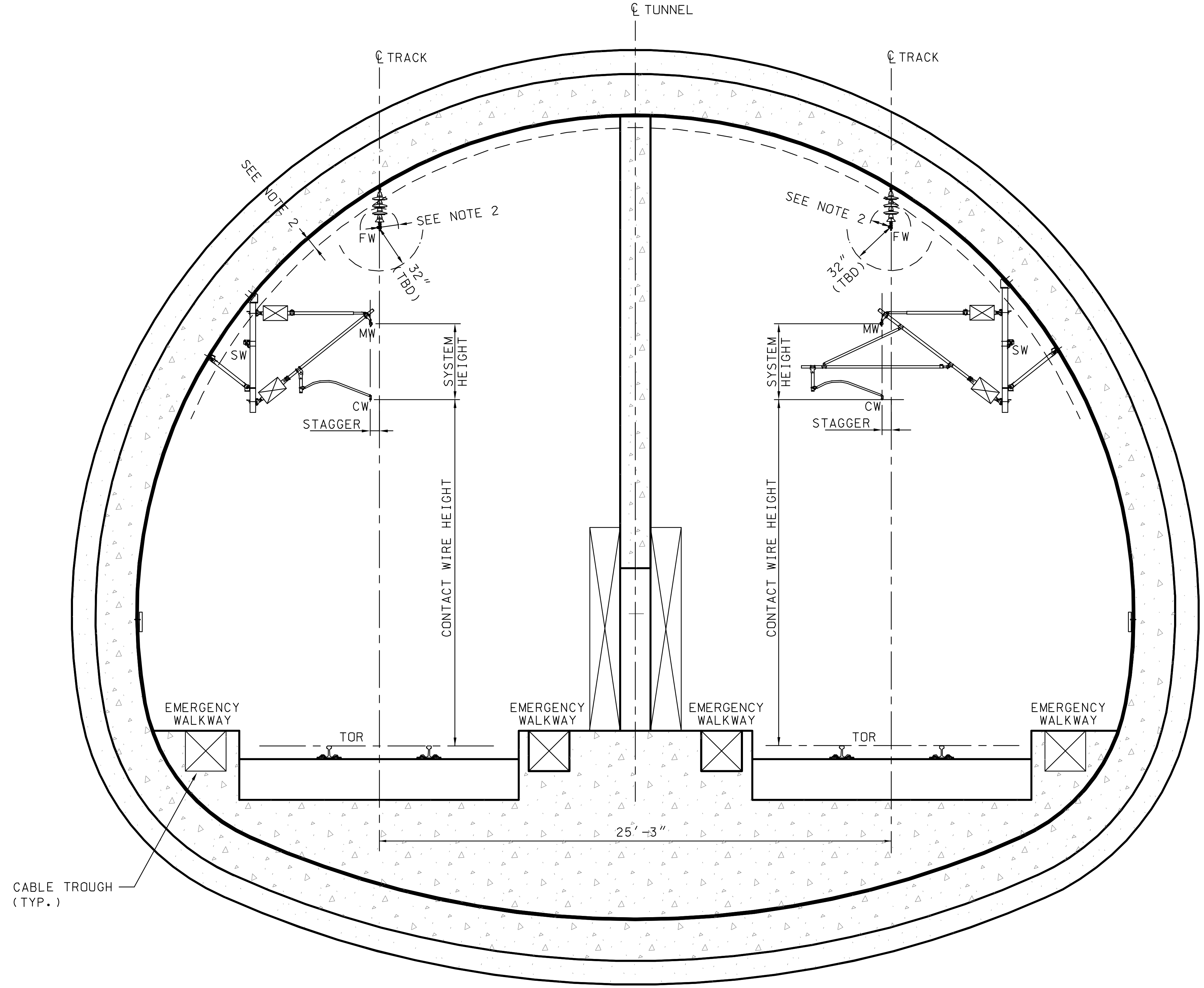
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS EQUIPMENT FOR
CIRCULAR TUNNEL - TANGENT TRACK

CONTRACT NO.
DRAWING NO. TM 3.2.2-B
SCALE NTS
SHEET NO.




MINED TUNNEL - TANGENT TRACK

NOTES:

1. ALL DIMENSIONS IN FEET AND INCHES UNLESS OTHERWISE STATED.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25kV AND GROUNDED PART OF STRUCTURE.

LEGEND:

| | |
|---|---|
| FW | NEGATIVE FEEDER WIRE |
| SW | STATIC WIRE |
| MW | MESSENGER WIRE |
| CW | CONTACT WIRE |
| SE | TRACK SUPERELEVATION |
| HRL | HIGH RAIL LEVEL |
| ℄ | CENTERLINE |
| TOR | TOP OF RAIL |

$FILE$ $TIME$ $DATE$ $USER$

| REV | DATE | BY | CHK | APP | DESCRIPTION |
|---|---|---|---|---|---|
| | | | | | |

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE 11-30-09

PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS EQUIPMENT FOR
MINED TUNNEL - TANGENT TRACK
220MPH

CONTRACT NO.
DRAWING NO. TM 3.2.2-C
SCALE NTS
SHEET NO.