California High-Speed Train Project

TECHNICAL MEMORANDUM

OCS Requirements

TM 3.2.1

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Revision	Date	Description
0	2 July 09	Initial Release
1	16 Aug 10	Updated to add wire temperature and bridge clearance requirements and other modifications

Note: Signatures apply for the latest technical memorandum revision as noted above.

Prepared by PB

for the California High-Speed Rail Authority

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:

Systems: NOT REQUIRED
Print Name Date

Infrastructure: NOT REQUIRED
Print Name Date

Operations: NOT REQUIRED
Print Name Date

Maintenance: NOT REQUIRED
Print Name Date

Rolling Stock: NOT REQUIRED
Print Name Date

Note: Signatures apply for the technical memorandum revision corresponding to revision number in header and as noted on cover.

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ABSTRACT

The California High Speed Train Project (CHSTP) will provide high-speed train service in the state of California with proposed terminal stations (end-of-line or end-of route) in Sacramento, San Francisco, Fresno, Bakersfield, Los Angeles, Anaheim and San Diego. Intermediate stations will serve locations along the alignment. For much of the alignment, high speed trains will operate along a dedicated track with stations that exclusively serve high speed train operations. There are also two locations (the Lossan and Caltrain corridors) where the proposed California High-Speed Rail (CHSR) line will operate within a shared right-of-way with conventional passenger railroad lines.

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

- Provide a general system description and define the general performance requirements of the overhead contact system
- Define the overhead contact system performance requirements for high speed
- Provide a general detailed description of the overhead contact system
- Define the environmental requirements and climatic conditions applicable to the CHSTP overhead contact system
- Define the electrical requirements including the electrical clearances applicable to the overhead contact system
- Define the overhead contact system mechanical requirements
- Define the overhead contact system structural requirements
- Define the grounding and bonding requirements applicable to overhead contact system
- Define the overhead contact system interface requirements in order to ensure that they will be adequately taken into account in the design, procurement, construction and testing processes
- Define the 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 and NFPA 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 requirements of the California High Speed Train Project to:

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It will thus promote safe and efficient operations both for high-speed rail train service on segments of the California High Speed Train Project (CHSTP) alignment that are dedicated to very high speed and for those in shared use corridors.

This memorandum presents data relating to the design, construction and testing of the overhead contact system that must be satisfied for high-speed train operation. Where available, it is based on best worldwide present practices and on present U.S. Federal and State Orders, guidelines and practices. Document searches were conducted to identify definitive criteria to be used for the CHST project 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. Additional guidance on the vehicle clearances, pantograph clearance envelopes, electrical clearances and electrical requirements, grounding and bonding requirements, mechanical requirements, and structural requirements to be used for high speed train operations are provided in separate documents.

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

1.2 STATEMENT OF TECHNICAL ISSUE

For high speed current collection, the pantograph – overhead contact system interface is extremely important, and is one of the most important technical issues when planning high speed train operations. Ensuring minimum or no interruption of contact continuity between the rolling stock pantographs and the overhead contact system cannot be realized without having carefully defined performance requirements of the overhead contact system, and of its interface with the pantographs.

In addition to the traction power collection, other technical items related to the overhead contact system performance must be defined for the design, construction and testing to ensure that the overhead contact system will satisfactorily provide for safe operation, and maximum reliability, availability, maintainability and safety.

They include electrical requirements, environmental requirements applicable to the CHSTP overhead contact system, mechanical and structural requirements, requirements applicable to the grounding and bonding of the system, interface requirements and construction and testing requirements.

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.

Arcing - The flow of current through an air gap between a contact strip and a contact wire, which results in erosion of both elements and is usually indicated by the emission of intense light.

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

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 pantograph 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 or rail level when not uplifted by the pantograph of an electric train.

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.

Dedicated Corridor - Segment along the CHSTP alignment where high speed trains operate exclusive of other passenger rail vehicles.

Dynamic Envelope of Pantograph - A clearance envelope around the pantograph static profile that takes into account under dynamic conditions the pantograph sway and pantograph uplift.

Electrical clearance - The clearance between live parts of either the OCS or a vehicle pantograph and grounded (earthed) parts of a fixed structure or a vehicle.

Electrical clearance – dynamic (passing) - Minimum clearance between live parts of either the OCS or a vehicle pantograph and grounded (earthed) parts of a fixed structure or a vehicle during the passage of an electrically powered vehicle equipped with a pantograph, or as a result of the dynamic movement of an energized conductor due to environmental conditions.

Electrical clearance - static - Clearance between live parts of either the OCS or a vehicle pantograph and grounded (earthed) parts of a fixed structure under static conditions, and when the OCS is not subjected to the passage of an electrically powered vehicle equipped with a pantograph or the effects of environmental conditions.

Insulated Overlap (or electrical overlap) - A length of the overhead contact system formed by cutting insulation into the out-of-running sections of the two adjoining and overlapping catenaries having between them a limited electrical clearance realized by an air gap. The contact and messenger wires of these two overlapping tension sections that terminate at opposite ends allow the creation of a sectionalizing point in the OCS creating adjacent electrical subsections energized by the same traction power supply source. The sections are required for operational and maintenance reasons, and for the passage of pantographs under power from one energized electrical sub-section to the next.

Interoperability - In the context of the European High Speed Lines, the capability of the European High Speed lines railway network to permit high speed trains to run safely and continuously with specified performances. It is based on legal, technical and operational conditions that must be fulfilled to satisfy the necessary requirements. Thus, for example, a German high-speed train satisfying the requirements of the Rolling Stock Technical Specification for Interoperability (TSI) is able to run safely and continuously on a French High Speed Line, the infrastructure of which satisfies the requirements of the various infrastructure Technical Specifications for Interoperability. These TSI design standards were developed specifically for the design, construction and operation of interoperable high-speed railways in Europe and are based on European and international best practices.

Live - An electrically energized circuit or component.

Live Part - A part or component connected to an energized circuit and therefore live and not insulated from the energized circuit.

Maximum contact force - The maximum value of the contact force.

Mean contact force - The statistical mean value of the contact force.

Minimum contact force - The minimum value of the contact force.

Overhead Contact System (OCS) - Also called 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 auxiliary wires (aerial feeder and aerial ground or static wires), supports, foundations, balance weight tensioning arrangements, electrical switches and isolators, and other equipment and 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.

Overlap - See Uninsulated Overlap and Insulated Overlap.

Pantograph - Current collector apparatus consisting of spring-loaded hinged arms mounted on top of electrically powered rail vehicles that provides a sliding electrical contact and collects current from the contact wire of an overhead contact system.

Pantograph current - Current that flows through the pantograph

Pantograph Clearance (or Pantograph Clearance Envelope) - A clearance envelope around the static pantograph profile.

Pantograph head - Pantograph equipment comprising the contact strips and their mountings.

Pantograph sway- Lateral displacements of the pantograph induced by the vehicle and pantograph under dynamic conditions of the electrical vehicle, which include gauge deviation, roll and lateral vehicle shock loads, and cross-track tolerance.

Phase Break - An electrical break consisting of an arrangement of insulators and grounded or non-energized wires separating two electrical sections of the Overhead Contact System supplied by two different traction power supply sources that may be out-of-phase and under which a pantograph may pass without shorting or bridging the phases.

Quasistatic force - Sum of pantograph static force and aerodynamic force at the particular train speed.

Section Insulator - A mechanical sectionalizing device installed in the overhead catenary providing separation between two adjacent catenary sub-sections both energized by the same traction power supply source which permits the passage of pantographs under power from one energized electrical sub-section to the next. .

Shared Use Corridor - Segment of the CHSTP alignment where high speed trains share ROW with other passenger railroads, i.e., Caltrain, MetroLink, and Amtrak

Shared Use Track - Segment of the CHSTP alignment where high speed trains operate on the same tracks as other passenger railroads, i.e., Caltrain, MetroLink, and Amtrak.

Span Length - The distance between two consecutive OCS supporting points.

Stagger - Offset of the contact wire from the projected or super-elevated track centerline at each registration point that causes the contact wire to sweep side to side over the pantograph head during vehicle operation and which helps to distribute wear over the pantograph carbon collector strips.

Static contact force - The mean vertical force exerted upward by the collector head on the overhead contact line, and caused by the pantograph-raising device, when the pantograph is raised and the vehicle is at standstill.

Steady arm - A lightly loaded registration arm that serves to hold or steady the contact wire at its correct lateral displacement.

Super-elevation - The difference in elevation between the outside rail and the inside rail on curved track, which is measured between the highest point on each rail head.

System Height - The vertical distance between the messenger and contact wires, at a support point.

Tensioning device - An assembly, typically placed at each end of a tension length, which comprises a balance weight arrangement that is used to maintain near-constant mechanical tension in one or more conductors of an auto-tensioned catenary.

Tension Length - Length of a catenary between its two termination points.

Trolley Wire - Alternative term for contact wire used for single wire OCS. See Contact wire and Overhead Contact System.

Uninsulated Overlap (or mechanical overlap) - A length of the overhead contact system where the contact and messenger wires of two adjoining tension sections overlap before terminating at opposite ends, thus allowing pantographs under power to transition from one tension section to the next.

Uplift - Lift of the contact wire and/or messenger wire due to the upward pressure of passing pantograph(s).

Yoke Plate - A plate or casting typically proportioned to accommodate unequal tensions in two or more wires or cables that are terminated on one side and which are balanced by a single terminating cable on the other side, permitting the use of only one balance weight arrangement for multiple conductors.

Acronyms

AAR	Association of American Railroads
AREMA	American Railway Engineering and Maintenance of Way Association
Caltrans	California Department of Transportation
CHST	California High-Speed Train
CHSTP	California High-Speed Train Project
CFR	Code of Federal Regulations
FRA	Federal Railroad Administration
GO	General Order
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.

Guidance for units of measure terminology, values, and conversions can be found in the Caltrans Metric Program Transitional Plan, Appendice B U.S. Customary General Primer (http://www.dot.ca.gov/hq/oppd/metric/TransitionPlan/Appendice-B-US-Customary-General-Primer.pdf). Caltrans Metric Program Transitional Plan, Appendice B can also be found as an attachment to the CHSTP Mapping and Survey Technical Memorandum.

2.0 DEFINITION OF TECHNICAL TOPICS

2.1 General

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

It is anticipated that the type of rolling stock for the CHSTP together with the pantograph type and the Overhead Contact System will not be selected prior to the completion of the 30% Design Level (Preliminary Engineering). Accordingly, the design guidelines included in this document are intended to accommodate the CHSTP preliminary engineering needs without precluding any potential high speed system technology. The design is to be conducted with the assumption that the high speed train set technologies, together with the high speed pantograph and the high speed overhead contact system, which will meet the CHSTP performance requirements, will be comparable to those of the French (Alstom – AGV), German (Siemens - ICE 3 - Velaro E, Japanese (Hitachi- Shinkansen N700), and Bombardier (AVE S-102). Refinements in the design and associated design elements may, therefore, be required following vehicle, pantograph, and overhead contact system supplier selection.

The traction power supply system for the California High Speed Train Project will be a 2x25 kV – 60 Hz system (i.e., 25 kV-0-25 kV) utilizing a 25 kV catenary and a negative (-25 kV) longitudinal feeder together with autotransformers spaced approximately every 5 miles (8 km) along the CHSTP right of way.

The CHSTP Overhead Contact System shall permit a maximum operational speed of 125 mph (200 km/hr) in existing corridors where high-speed passenger trains and existing passenger trains may both operate on the same main line shared tracks. In addition, it is envisaged that time-separated freight traffic may also operate over a few miles of the electrified tracks these shared use corridors.

Elsewhere, on dedicated high-speed sections, the CHSTP Overhead Contact System shall permit a maximum operational speed of 220 mph with consideration that faster operation will not be unnecessarily precluded in the future.

2.2 LAWS, CODES AND STANDARDS

2.2.1 NORTH AMERICAN RECOMMENDED PRACTICE AND LEGAL REQUIREMENTS IN CALIFORNIA

AREMA Manual

The primary orientation of the American Railway Engineering and Maintenance of Way Association "Manual of Railway Engineering" (AREMA Manual) is to provide guidance for the engineering of railroads moving freight at speeds up to 79 mph 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 CPUC 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 and legal rules for Overhead Electric Line Construction are defined in PUC GO 95. However, the current version of PUC GO 95 is not applicable to 25 kV electrified overhead contact systems. CPUC General Orders would require amendment or specific rules to be adopted to allow for the construction and operation of a 25 kV electrified railroad.

2.2.2 CHSTP Design Criteria for the Overhead Contact System

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. 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 for the Overhead Contact System is based on a review and assessment of available information, including the following:

- AREMA Manual
- California Public Utilities Commission General Orders
- Amtrak guidelines and present practices
- Federal and State Orders guidelines and present practices
- Caltrain Design Criteria (April 15, 2007)
- Existing ASCE, IEEE and NFPA standards and guidelines where applicable
- Technical Specifications for Interoperability of European High-Speed lines
- Other 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.

It is to be noted that Sections 1 to 8 and 12 of Chapter 33 ''Electrical Energy Utilization'' and Section 1.8 of Chapter 28 "Clearances" of the AREMA Manual can be referenced for guidance for overhead electrification. However, these sections of the AREMA Manual do not address high-speed or very high speeds which are only succinctly addressed in Chapter 17 of the same manual. For this reason the Technical Specifications for Interoperability of European High Speed lines (TSI) are referenced, since these design specifications were developed specifically for the design, construction and operation of interoperable high-speed railways in Europe and are based on European and international best practices.

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, the Design Manual will present design standards and criteria 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 as 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

Data applicable to overhead contact systems used overseas for existing high-speed railways, as well as specific data and American and International standards or guidelines applicable to the CHSTP overhead Contact System were collected along with the CHSTP characteristics that are applicable to sections of the CHSTP dedicated to very high speed operation only and for sections of the CHSTP that will support operations in shared use corridors for both high-speed trains and conventional passenger trains. Additionally, it is envisaged that time-separated freight traffic may also operate over a few miles of the electrified tracks in the shared use corridors.

Based on those data, the following OCS requirements are considered to be the guiding criteria for development of the overhead contact system for the CHSTP.

3.2 GENERAL OVERHEAD CONTACT SYSTEM REQUIREMENTS

3.2.1 OVERHEAD CONTACT SYSTEM GENERAL DESCRIPTION AND REQUIREMENTS

3.2.1.1 System Description and General Performance Requirements

In order to minimize the number of substations and EMC problems along the CHSTP alignment, the line will be fed by a 2x25 kV, 60 Hz configuration, in accordance with Technical Memorandum 3.1.1.1 "Traction Power 2x25 kV Autotransformer Electrification System & Supply Voltages" utilizing Traction Power Supply Stations, Switching Stations and Paralleling Stations (with autotransformers).

The Traction Power Supply Stations (SSTs) are connected to HV Utility Supplies and spaced approximately every 30 miles (48 km), while the Switching Stations (SWSs) are spaced approximately at mid distance between SSTs, i.e., at about 15 miles (24 km) from a SST, and the Paralleling Stations (PSs) are spaced approximately at 5 miles (8 km) intervals. At these locations, the transformer parallels the Track 1 and Track 2 power supplies and balances the two 25 kV supplies (longitudinal feeder and catenary) with respect to each other.

At the Traction Power Supply Stations and Paralleling Stations, the center tap of the respective supply transformers and auto-transformers is connected to and referenced to the running rails.

The Overhead Contact System, which provides electric traction power to the pantographs of the electric trains using the CHSTP route, is therefore configured as a 25 kV-0-25 kV arrangement with a catenary at a nominal voltage of 25 kV to ground and a negative (so called -25 kV) longitudinal feeder in phase opposition with the catenary. The OCS shall transfer electric power from the Traction Power Supply Stations to train(s) under all operating conditions and provide reliable operation under all environmental conditions detailed in Section 3.2.1.2.1.

The OCS shall provide uninterrupted traction power collection (except at Phase Breaks) at the maximum operating speed of 220 mph (354 km/hr) (with consideration that faster operation in the future will not be unnecessarily precluded) along the CHSTP sections dedicated to high-speed and at a maximum operating speed of up to 125 mph (200 km/hr) in shared used corridors.

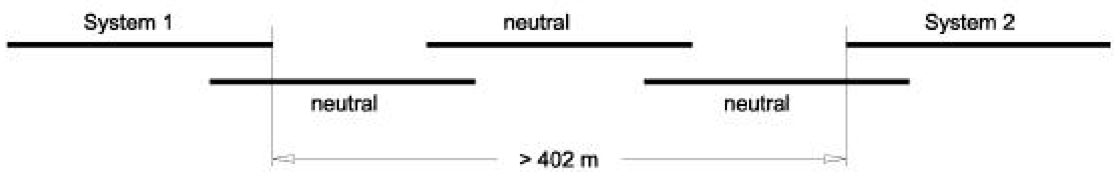
To allow unrestricted bi-directional working, enabling trains to continue operation under emergency conditions and to facilitate routine OCS maintenance, the CHSTP OCS will be divided into electrical sections and sub-sections. On the main line, only Phase Breaks and Insulated Overlaps shall be used for power supply sectionalizing purpose – mechanical section insulators will not be permitted.

For the CHSTP, the OCS phase break arrangements are located in front of SWSs (and if required in front of SSTs) to electrically separate two successive catenary electrical sections fed by different 25 kV AC sources; i.e., not of the same phase. The electric trains shall therefore be able to pass through the phase break arrangement without establishing an electrical connection between the successive electrical sections which are fed from different phases. This shall be realized at the maximum operating speed and with the train pantographs raised and in contact with overhead catenary, but with the pantograph breaker off.

Two types of designs of phase separation sections may be adopted on the CHSTP sections dedicated to very high speed, either:

- a phase break design where all the pantographs of the longest trains can be positioned within the neutral section, which means that the length of this neutral section shall be at least 1319 feet (402 m),

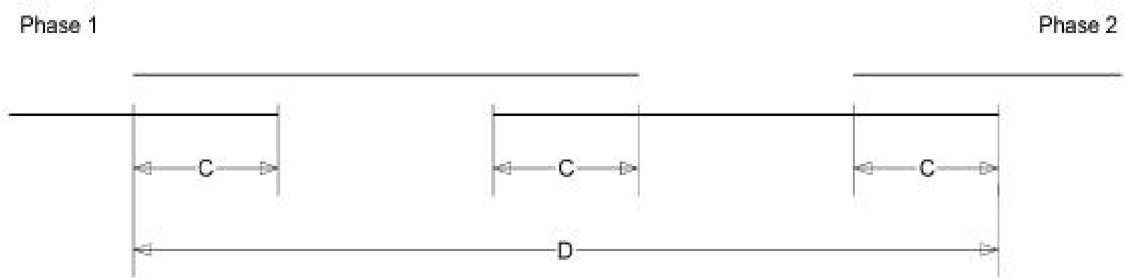
Arrangement of system separation section with long neutral section



or:

- a shorter phase break separation with an overall length that is less than 466 feet (142 m), including clearances and tolerances, and which is constituted of three insulated overlaps as shown below.

Arrangement of phase separation with short neutral section



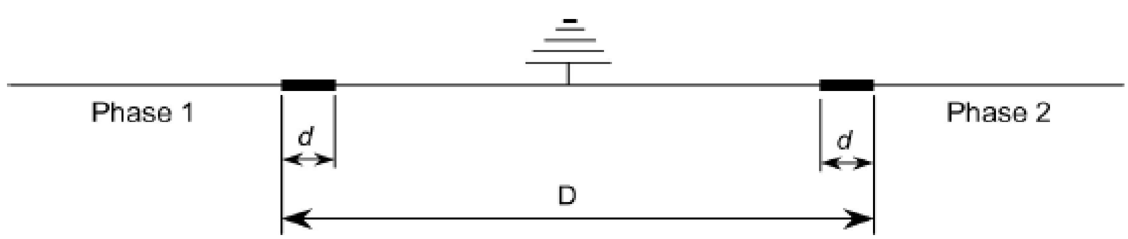
Length D < 142 m

Overlapping sections C: pantograph in contact with two contact wires.

Adequate means shall be provided to allow a train that is stopped within the above phase break arrangements to be restarted; i.e., the neutral section shall be connectable to the adjacent sections by remotely controlled switches/isolators.

On shared use corridors where the maximum operation speed is 125 mph (200 km/hr), the design of phase breaks, as specified above, can be adopted. In addition, a third phase break design using mechanical section insulators and having its center section connected to the current return path / ground may also be adopted. This neutral section is generally formed by insulating rods or double section insulators with D ≤ 27 feet (8 m) and shall be of a proven and reliable phase break design suitable for 125 mph (200 km/hr) operational speed.

Separation Section with Insulators



The design of the OCS phase break arrangement shall be interfaced with the rolling stock (to confirm the number and for the spacing of pantographs, which shall be 656 feet [200 m]) and with the signaling system (to confirm the exact mileage locations and lengths of the OCS phase break arrangements). Refer to Section 3.2.2 for these interfaces.

Insulated Overlaps shall be used on the main line, for operational and maintenance reasons, to separate successive electrical sub-sections are described in Section 3.2.1.3.1 of this Technical Memorandum.

Elsewhere, on diversionary tracks (turn-outs) and stabling tracks, mechanical Section Insulators permitting operations at speeds up to 125 mph (200 km/hr), would be acceptable in lieu of insulated overlaps for sectionalizing purposes.

Several CHSTP technical memoranda supplement this “OCS Requirements” Technical Memorandum:

- The pantograph static, dynamic and electrical envelopes together with vertical space required for the OCS between supports are presented in the “Pantograph Clearance Envelopes” Technical Memorandum (TM 3.2.3).
- The 2x25 kV grounding and bonding network for the CHSTP is described in the ‘‘CHSTP Grounding and Bonding’’ Technical Memorandum (TM 3.2.6).
- The structural requirements applicable for the CHSTP OCS are described in the ‘‘OCS Structural Requirements’’ Technical Memorandum (TM 3.2.2).

3.2.1.2 Overhead Contact System Performance Requirements for High-speed

3.2.1.2.1 OCS Dynamic Performance

At the high speeds envisaged for the CHST, the high speed current collection and the interaction between the overhead contact system and the pantograph represent very important aspects in establishing a reliable power transmission without undue disturbances. Indeed, ensuring minimum or no interruption of contact continuity between the rolling stock pantographs and the overhead contact system cannot be realized without having carefully defined performance requirements of the overhead contact system, and of its interface with the pantographs.

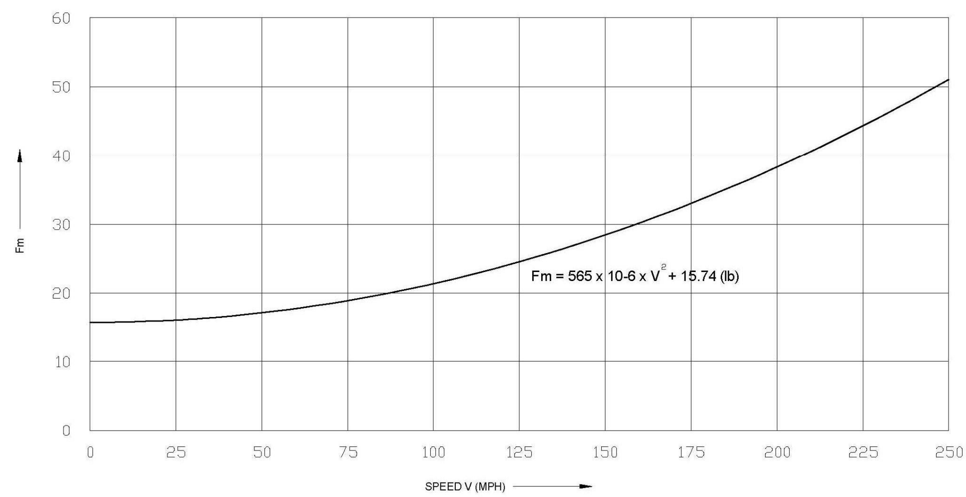
This interaction is mainly determined by:

- The static and aerodynamic effects which depend on the design of the pantograph and the nature of the contact strip of the pantograph. For 25 kV ac overhead contact systems, the static force shall be adjustable between 9 and 27 pounds force (40 and 120 N) and the nominal static force is to be 15.75 (+4.5/-2.25) pounds force (70 +20/-10 N). Only pantographs designed and proven for very high speed performance shall be considered for the CHST.
- The number of pantographs in service per train and the pantograph spacing (which is necessary to confirm the OCS phase break design arrangement and for which a 656 feet (200 m) spacing is required) have a fundamental impact on the quality of current collection, since the effects of each pantograph can interfere with others running under the OCS.
- The compatibility of the contact strip material with the contact wire regarding limitation of wear on those components. On high-speed lines, there should be only one type of current collector head used for all trains and a carbon-based material is recommended for the collector strips to minimize contact wire wear.
- The protection of the pantograph and overhead contact line equipment in case of a broken pantograph collector strip. Pantographs shall be equipped with a fail safe device that will detect any failures of the contact strips and will trigger the lowering of the pantograph in case of a failure.
- The dynamic behavior of the pantograph-contact wire combination and its impacts on current collection quality – the aim being to achieve a continuous and uninterrupted power supply to the vehicles without disturbances.

Concerning the dynamic behavior requirements, the quality of the current collection shall be assessed by the following measurable parameters:

1) Either by the counting of arcing, which can only be carried out by on-site testing after construction is complete, or by determining at the design stage the mean value (F_m) and the standard deviation (σ) of simulated contact forces. The mean contact force is the mean value of the forces due to static and aerodynamic actions. It is equal to the sum of static contact force and the aerodynamic force caused by the airflow on the pantograph elements at the considered speed. The mean uplift force is a characteristic of a particular rolling stock/pantograph combination.

In this context, F_m represents a target value which should be achieved to ensure on the one hand current collection without undue arcing, but which should not be exceeded on the other hand to limit wear and hazards to current collection strips. The target for mean contact force F_m for the CHSTP ac system is shown in the following graph as a function of the running speed:



Graph of the F_m Target value

In case of trains with multiple pantographs simultaneously in operation, the mean contact force F_m for any pantograph shall be not higher than the value given in the above graph, since the current collection criteria shall be met for each individual pantograph.

The maximum contact force (F_{max}) is usually within the range of F_m plus three standard deviations σ for level grade sections, while higher values may occur elsewhere with other track conditions.

In addition to the minimum and maximum contact forces, the statistical value $F_m - 3\sigma$ (which represents the value at which loss of contact between the pantograph and the contact wire may occur) permits the assessment of the consistency of contact between the pantograph and the overhead contact system. The value $F_m - 3\sigma$ shall be positive to avoid contact losses.

2) The contact loss percentage. For quality current collection, the loss of contact of the pantograph strip from the contact wire shall be as low as possible, since any loss of contact may generate an electric arc which will cause rapid wear, and the possibility of a circuit breaker switching in the case of an excessive arc due to an extended loss of contact. For sections dedicated to very high speed, the on-site measured arc percentage NQ shall be ≤ 0.2 % at maximum line speed, and for the maximum speed of 125 mph (200 km/hr) in shared use corridors NQ shall be ≤ 0.1 %. For a given vehicle speed, this arcing percentage characteristic, NQ, is given in % by the following formula:

$$NQ = \frac{\Sigma\, t_{arc}}{t_{total}} \bullet 100$$

and the minimum arc duration to be taken into account is 5 ms.

3) The vertical movement of the contact point (which is the point of mechanical contact between a contact strip and the contact wire) at the maximum operational speed. This criterion permits the assessment of the behavior of the OCS and pantograph, since 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. This shall be verified by measurements or by simulations at the maximum speed by using the mean contact force F_m for the longest span length, but need not to be verified for uninsulated or insulated overlap spans. It is presented as a graph of the contact point vertical position versus distance in span to evaluate the extent of the vertical movement. The maximum difference between the highest and the lowest dynamic contact point height within one span shall be less than 3.15 in. (80 mm) at the maximum operational speed on the sections dedicated to very high speed, and less than 3.94 in. (100 mm) at the maximum speed of 125 mph (200 km/hr) in shared use corridors.

4) The propagation speed of the waves created in the contact wire by the pantograph forces. The speed of wave propagation in the contact wire is another characteristic parameter for assessing the suitability of a contact line for high-speed operation. This parameter depends on the specific mass and the stress of the contact wire. Based on European experience, the maximum operating speed should be not more than 70% of the wave propagation speed, which means that for a 220 mph (354 km/hr) maximum operational speed, the wave propagation speed shall be above 314 mph.

Conformance to the above criteria will have to be confirmed by the Overhead Contact System supplier by means of a dynamic OCS-pantograph dynamic interaction simulation or equivalent records of on-site test results for speeds above 220 mph (354 km/hr). Notwithstanding the above, the Overhead Contact System of the CHSTP shall be a proven system capable of current collection at 220 mph (354 km/hr) in sections of the CHSTP dedicated to very high speed and for satisfactory operation at 125 mph (200 km/hr) in shared use corridors.

For uniformity and maintainability purposes, the designs of the OCS for 125 mph (200 km/hr) and 220 mph (354 km/hr) shall generally be similar using the same conductors and equipment. However, shared operations with high speed trains and other trains having a higher load gauge will require a higher contact wire height in shared use corridors and may consequently require larger or heavier OCS steady arm arrangements, which must be acceptable for 125 mph (200 km/hr) operations. The track alignment in existing corridors includes heavy curves, which may also result in adaptations or modifications to the basic CHSTP OCS design, such as the need for different mechanical tensions in the messenger and contact wires.

3.2.1.2.2 OCS RAMS Requirements

In terms of RAMS requirements, the design performance of the high speed overhead contact system for the CHST shall provide a guaranteed very high level of Reliability, Availability, Maintainability and Safety through a RAMS analysis, which can be demonstrated, through data gathered during previous operations of this high speed OCS system.

3.2.1.3 Overhead Contact System Detailed Requirements

3.2.1.3.1 OCS Detailed Description

The catenary consists of a bronze or other copper alloy bare messenger wire supporting, by means of copper alloy hangers, a solid copper (or copper alloy) contact wire (refer to OCS Standard Drawings). The contact and messenger wires shall be separately auto-tensioned such that the mechanical tension in each conductor shall remain near-constant throughout the designated operating temperature range.

The catenary is supported from cantilever frames designed to provide the required system height and to register the correct stagger of the wires relative to the track center line. Refer to CHSTP OCS Standard Drawings for specific requirements for very high speed and for speeds up to 125 mph.

An aerial ground wire, connected at regular intervals to the track via impedance bonds, is run alongside the catenary to inter-connect each OCS supporting structure, such that all OCS non-live metallic supports are at the same ground (and track) reference potential (refer to OCS Standard Drawings for requirements for very high speed and for speeds up to 125 mph).

The negative longitudinal feeder is run at the top of the OCS poles, preferably on the track side (refer to OCS Standard Drawings for specific requirements for very high speed and for speeds up to 125 mph), but may also be positioned on the field side when the right-of-way width or overhead structure configuration dictates (refer to OCS Standard Drawings for details).

In sections dedicated to very high speed, the tunnels should be of sufficient cross-sectional area to permit the installation of bare feeder wires. However, in the shared use corridors, tunnels of smaller sections (refer to OCS Standard Drawings for speeds up to 125 mph) may necessitate the installation of reduced system height catenary equipment and may not permit the installation of bare longitudinal feeders. In such cases, insulated feeder cables would have to be used in lieu of bare feeder conductors.

The overhead contact system shall be free-running under overhead bridges – no OCS or feeder supports attached to the bridge structures. New bridges shall be designed to accommodate a free-running clearance height. In shared use corridors, existing bridge clearances will have to be reviewed to determine whether free-running OCS arrangements can be accommodated, which should be the goal in these locations as well.

For constructability and maintenance purposes, the catenary conductors are installed in tension lengths. Uninsulated or mechanical overlaps shall be utilized to allow pantographs to transition smoothly from one tension length to the next under power. Refer to CHSTP OCS Standard Drawing OCS 006 for very high speed and OCS 016 for speeds up to 125 mph.

For sectionalizing purposes, as mentioned above in Section 3.2.1.1, some overlaps shall be insulated. In this arrangement, the contact and messenger wires of the two overlapping tension lengths shall have insulation cut into the out-of-running sections of the overlap catenaries, having between them a limited electrical clearance realized by an air gap. The insulated overlap thus provides a sectionalizing point in the OCS as required for operational and maintenance reasons, but allows pantographs to transition from one energized electrical sub-section to the next one under power. Refer to CHSTP OCS Standard Drawing OCS 007 for very high speed and OCS 017 for speeds up to 125 mph.

3.2.1.3.2 Catenary conductor, hanger, contact wire height and stagger, auto-tensioning and tension length requirements

In order to ensure that the CHSTP catenary system will have a known and proven dynamic behavior that will make it suitable for an operational speed up to 220 mph (354 km/hr) on sections dedicated to very high speed and up to 125 mph (200 km/hr) on shared use corridors, the catenary characteristics, including those of the contact and messenger wires and of their mechanical tensions, together with the hanger system shall be those of an existing proven high-speed overhead contact system.

The messenger wire shall be kept vertically in line ("plumb") with the contact wire and hangers shall support the contact wire from the messenger wire at regular intervals. The hanger design shall be a current carrying hanger, thereby eliminating the need for in-span jumpers, and shall ensure that there is no "hard spot" on the contact wire. The length and position of the hangers shall be such that they provide the correct contact wire profile for high-speed current collection.

The contact wire shall be pre-sagged in each span. For CHSTP sections dedicated to very high speed, the amount of pre-sag required shall preferably be calculated as 1/2000 of the span length, measured at mid span. In shared use corridors, the amount of pre-sag required for speeds up to 125 mph (200 km/hr) shall be calculated as 1/1000 only of the span length, measured at mid span. Refer to CHSTP OCS Standard Drawing OCS 001 for very high speed and OCS 011 for speeds up to 125 mph.

The contact wire shall be installed and maintained at a nominally constant and minimum height of 17'- 5" (5309 mm) at OCS supports on sections dedicated to very high speed, where the maximum vehicle load gauge height will be 14'- 9¼" (4500 mm) in accordance with the ''Structure Gauge'' Technical Memorandum (TM 1.1.10). The height difference at each adjacent structure shall be less than ½" (13 mm) to provide the constant contact wire height that is required for satisfactory pantograph current collection at high speed.

In shared use corridors, where the maximum operating speed is 125 mph (200 km/hr), and where high speed vehicles will share the track with other American passenger cars of a maximum vehicle load gauge height of 17 ft. (5182 mm) in accordance with the ''Structure Gauge'' Technical Memorandum (TM 1.1.10), the contact wire shall generally be set a height of 18'- 9" (5715 mm) at supports, takes into consideration where time-separated freight traffic may also operate on a few miles of the electrified tracks in shared use corridors. The pantograph static, dynamic and electrical envelopes together with vertical space required for the OCS between supports are presented in the "Pantograph Clearance Envelopes" Technical Memorandum (TM 3.2.3).

The contact wire height transition between sections dedicated to very high speed and a shared use corridor shall be achieved in areas where the speed does not exceed 125 mph (200 km/hr). Based on the maximum authorized speed, the maximum contact wire gradients and the corresponding maximum gradient changes shall not exceed the following values:

Maximum speed	Maximum contact wire gradient	Maximum contact wire gradient change
> 125 mph	0	0
125 mph	2/1000	1/1000
100 mph	3.3/1000	1.7/1000
75 mph	4/1000	2/1000
60 mph	6/1000	3/1000
45 mph	8/1000	4/1000
30 mph	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. The stagger shall normally be set at ±8 in (203 mm). On curved track, the staggers shall be calculated on a case by case basis taking into account OCS span length, track super-elevation, radius of track curvature, and wind speed.

The method of auto-tensioning the OCS catenary conductors shall be by means of balance weight tensioning devices. For very high speed, the tensions are to be applied to the contact and messenger wires individually by using separate balance weight tensioning devices and anchoring positions, as shown on CHSTP OCS Standard Drawings. For speeds up to 125 mph (200 km/hr) in the shared use corridors, the messenger and contact wires will be auto-tensioned using a yoke plate and one common balance weight arrangement.

The mechanical tension in each of the contact and messenger wires shall be automatically maintained throughout a temperature range of 25°F to 176°F (-4°C to 80°C) in the above grade sections, which will also apply to the first 1300 ft. (396 m) in tunnels. After the first 1300 ft. (396 m), the temperature range for auto-tensioning of the conductors shall be 35°F to 155°F (2°C to 68°C).

Maximum tension lengths from anchor to anchor shall not exceed 4000 ft. (1219 m) in tunnels and adjacent to traction power supply stations and 4600 ft. (1402 m) in open route. Exceptions up to 5000 ft. (1524 m) may be allowed on a case-by-case basis. At approximately mid-distance between auto-tension termination anchors, mid-point arrangements shall be installed, such that the maximum half tension lengths do not exceed 2000 ft. (610 m) in tunnels and 2300 ft. (702 m) in open route. Refer to CHSTP OCS Standard Drawings for additional details.

3.2.1.3.3 Environmental and climatic requirements

The CHSTP Overhead Contact System shall provide for reliable operation under the conditions given below.

Humidity: The OCS equipment for above grade sections of the alignment shall be resistant to heavy fog and high humidity up to 100% humidity. The OCS shall be designed to operate without failure or deterioration in all humidity conditions found in California. These include 100% humidity conditions, including rain and fog and a salt-laden atmosphere in sections of the open route near the ocean, and 100% humidity in tunnels.

Ice: In accordance with Figure 7.1 ''Ground snow loads'' of the ASCE Standard "Minimum Design Loads for Building Structures", snow and ice along the CHSTP alignment are quite rare. In accordance with Table 250-1 and Figure 250-3(a) of the NESC, the OCS design should not take into account any ice thickness for loading design purpose.

Wind: The ASCE Standard "Minimum Design Loads for Building Structures" defines the basic wind speed corresponding to the wind load for wind force resisting structure as a three (3) second gust speed at 33 feet (10.06 m) above ground for open terrain, exposure C and associated with an annual probability of 0.02 (50 year mean recurrence interval) of being equaled or exceeded. This basic wind speed is, in accordance with Figure 6-1 of the ASCE Standard, Vbws = 85 mph 38 m/s) for the State of California. This maximum three (3) second gust speed corresponds, in accordance with Figure C6-1 of the ASCE Standard, to a mean maximum hourly wind speed of (Vbws/1.52 =) 56 mph (25 m/s) approximately.

For OCS design, 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:

- the operational wind speed shall be used to compute catenary support, catenary wire displacement for pantograph security and maximum span length calculations and will be taken as Vop = 60 mph (26.8 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 CHSTP route.

The wind velocity pressure qz shall be calculated by the NESC formula:

$$q_z = 0.00256\, V^2 K_z\, G_{RF}\, I\, C_f\, A \quad \text{in lb/sq ft}$$

(equivalent to $$q_z = 0.613\, V^2 K_z\, G_{RF}\, I\, C_f\, A \quad \text{in N/m}^2$$

where:

- 0.00256 (0.613 in the metric system) is the velocity pressure numerical coefficient reflecting the mass density of air for the standard atmosphere,
- K_z is the velocity pressure exposure coefficient,
- V is the basic wind speed (3 second gust wind speed at 33 feet (10.06 above ground for open terrain, exposure C; i.e. V_{bws})
- G_{RF} is gust respond factor,
- I is the importance factor (I being equal to 1.00 for OCS), and
- C_f is the force coefficient shape factor,
- A is the projected wind area.

Note: K_z, V and G_{RF} 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). The wind velocity pressure shall be increased for very exposed areas by the ASCE factor K_{zt} to take into account these very exposed area cases.

Loads due to wind for OCS structural calculations shall be multiplied by the load factors given by Table 253-1 of the NESC.

Please refer to the Technical Memoranda ''OCS Structural Requirements'' (TM 3.2.2).

Temperature: For the purpose of the CHSTP, based on typical and extreme ambient temperatures recorded along the CHSTP route, ambient temperatures considered for the design, range from 25°F to 120°F(-4°C to 49°C) .

Note: In long tunnels, only the first 1300 ft. of catenary from each portal is subject to external ambient temperature variations. Nevertheless, after the first 1300 ft, the ambient temperature in tunnels shall be considered as ranging from 35°F to 105°F (-2°C to 41°C) and the messenger and contact wires in tunnels are to be regulated with automatic tensioning.

Atmospheric Pollution: The OCS equipment above grade sections of the alignment shall be resistant to polluted atmospheres that may occur in highly industrialized areas, together with fog and marine atmosphere coming from the ocean. In tunnels and cut & cover box structures of the shared use corridors where high speed trains and other passenger trains traffic could be combined with diesel freight trains, OCS tunnel equipment shall be resistant to such tunnel corrosive atmosphere.

3.2.1.3.4 Electrical requirements

The OCS static and dynamic electrical clearances that are recommended values to be used for the CHSTP, based on UIC clearances and clearances used on very high-speed lines in Europe, are listed in the following table:

Clearances	For CHSTP sections dedicated to very high speed		For share used corridor for speeds up to 125 mph (200 km/hr)	
	Static (in.)	Dynamic (in.)	Static (in.)	Dynamic (in.)
Normal	12.6” (320 mm)	8.7” (220 mm)	12.6” (320 mm)	8.7” (220 mm)
Minimum	12.6” (320 mm)	8.7” (220 mm)	10.6” (270 mm)	6.7” (170 mm)

The minimum clearance for ancillary conductors (the 25 kV negative feeder) from energized parts of the OCS to grounded structures under worst case conditions is specified in (the soon-to-be-published) AREMA Ch 33 Table 33-2-2 to be 10.5” (270 mm) and this shall be adopted for the CHSTP.

In a 2x25 kV ac system, there is a 180° phase difference between parts common to the energized negative feeder and parts common to the energized catenary system. The minimum clearance between these elements shall be as stipulated in Table 10 of EN 50119: 2001, which is 21.3” (540 mm) under static conditions or 11.8” under dynamic conditions.

3.2.1.3.5 Mechanical requirements

For pantograph security purposes, the permissible lateral deflection of the contact wire in relation to the track centreline under the action of crosswind shall be ≤ 15¾ in (400 mm).

For planning purposes and for a contact wire height of 18'-9"(5715 mm) or less, a 210 ft. (64 m) maximum along track spacing of OCS supporting structures should be considered in tangent track. Such a maximum along track OCS pole spacing should, however, be reduced in curves and could range from say 190 ft. (58 m) for a 25,000 ft (7,620 m) radius curve to 90 ft (27.5 m) for a 1000 ft (305 m) radius curve.

At the maximum operational speed, the uplift of the contact wire be up to 6.9" (175 mm) at mid span, and is expected to be up to five 4.9" (125 mm) at the steady arm point. In order to provide for safety under all conditions (including strong winds and slight misadjustments of pantographs), the dynamic pantograph envelope shall consider twice the value of the estimated or simulated uplift S_0 at the support point, i.e. 9.8" (250 mm) minimum. The design of the OCS cantilever and registration shall consequently allow for a steady arm uplift clearing at least the dynamic pantograph envelope, and thus allow for a minimum uplift of 9.8" (250 mm).

Where the 18'- 9" (5715 mm) contact wire height is used on tracks in shared used corridors that will be shared by both high speed trains and existing passenger trains, a maximum uplift of 3.9" (100mm) is expected for a speed of 125 mph (200 km/hr), and thus the dynamic pantograph envelope for 18'- 9" (5715 mm) contact wire height shall consider a 7.9" (200mm) uplift at the support point. The design of the OCS cantilever and registration shall consequently allow for a steady arm uplift clearing at least the dynamic pantograph envelope, and thus allow for a minimum uplift of 7.9" (200mm) for the 18'- 9" (5715 mm) contact wire height. For reduced speeds to a maximum of 125 mph (200 km/hr) and with traffic of conventional passenger cars not having UIC rolling stock characteristics, the design considers the recommendation of Part 2 of Chapter 33 of the AREMA Manual for the determination of the pantograph sway. Please refer to ''Pantograph Clearance Envelopes'' Technical Memorandum (TM 3.2.3) that provides the static, dynamic and electrical clearance envelopes of the pantograph and the vertical space required for OCS for very high speed dedicated sections and for shared use corridors.

3.2.1.3.6 Structural requirements

In above grade sections, OCS structures are to be galvanized H-section wide flange beams and are to be designed and manufactured to the relevant steel standards.

Where the OCS is closely supported, such as at overlaps and turnouts, multiple cantilevers will be attached to a single structure. The applied loads shall not cause twisting of the structure by more than five (5) degrees, so a heavier section pole may be required.

The OCS supporting structures shall be calculated in accordance with relevant American standards (NESC, ASCE, ANSI). In addition, the maximum dynamic pole deflection across track, due to wind loading, shall not exceed 2 inches (51 mm) at contact wire level.

For multi-track areas where independent poles cannot be installed between tracks, portal structures using drop tubes, which permit the maintenance of 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, have to be used at crossovers and intermediate passenger stations where single poles cannot be installed. Headspan arrangements may be used, if considerations dictate, to equip maintenance yard multi-track areas or at passenger station approaches in shared use corridors,.

In tunnels and cut and cover structures, 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, bolted connections suitable for the loading conditions and material to which the support is attached shall be used. In order to reduce the risk of drilling into rebars, specialized equipment should be used to locate the reinforcing bars before drilling. The minimum distance from a reinforcing bar to a drilled hole shall be 2 inches (51 mm).

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 6ft 6in (1.98 m) approximately above rail level. For supports located in tunnels, the number plate shall be attached to the wall using suitable fixings.

3.2.1.3.7 Overhead Structure Clearance Requirements

In addition to the pantograph envelope indicated in TM 3.2.3.3, the minimum vertical clearance of the overhead structure shall also consider the vertical clearance between the energized parts of OCS and the feeder cable when the feeder cable is located at track side and is supported by the same structure, as indicated in the directive drawings of TM 3.2.1. This electrical clearance, as indicated in EN50119 Table 10, shall be 21.3" (540 mm) between the feeder and the OCS. With respect to NESC Rule 235C2a, for voltages over 50 kV, the clearance values given in NESC Table 235-5 shall be increased by 0.4" (10 mm)/kV over 50 kV. Table 235-5 Column 4 (Same Utility) Case 2a and Case 2d gives clearance values of (16" + 0.4"/kV over 8.7 kV) up to 50 kV which, for the 2x25 kV conductors, translates to [16 + ((50-8.7) x 0.4) + ((60-50) x 0.4)] = 36.5" (927 mm), allowing for a maximum operating voltage of 30 kV on each conductor. The value derived from NESC shall be used in calculating the required vertical clearance for conductors which are not attached to the overhead structure.

The required vertical clearance for new structures, without OCS conductor support attachments, is 27' (8.23 m). The required vertical clearance for existing structures, without OCS conductor support attachments, is 24' (7.32 m). The calculations, taking the above clearance requirement into consideration, are shown below in Table 3.2A and Table 3.2B.

	Contact Wire Height	System Depth	Feeder Wire Clearance	Construction Tolerance	Electrical Clearance	Total
Dedicated Track Area	17'- 5"	5'- 3"	36.5"	2"	12.6"	26'-11.1"
Dedicated Track Area	5308 mm	1600 mm	927 mm	51 mm	320 mm	8206 mm
Shared Use Corridor	18'- 9"	4'- 0"	36.5"	2"	12.6"	27'- 0.1"
Shared Use Corridor	5715 mm	1219 mm	927 mm	51 mm	320 mm	8232 mm

Table 3.2A Required Vertical Clearance for New Overhead Structures with Feeder at Track Side

	Contact Wire Height	System Depth	Feeder Wire Clearance	Construction Tolerance	Electrical Clearance	Total
Dedicated Track Area	17'- 5"	5'- 3"	0"	2"	12.6"	23'-10.6"
Dedicated Track Area	5308 mm	1600 mm	0 mm	51 mm	320 mm	7279 mm
Shared Use Corridor	18'- 9"	4'- 0"	0"	2"	12.6"	23'-11.6"
Shared Use Corridor	5715 mm	1219 mm	0 mm	51 mm	320 mm	7305 mm

Table 3.2B Required Vertical Clearance for Existing Overhead Structures with Feeder at Field Side

Notes:

1. Table 3.2A assumes the messenger wire is the highest energized point below the negative feeder.
2. Table 3.2B assumes the negative feeder is not higher than messenger wire height.
3. The clearances defined here assume the overhead structures are no more than 160' in length along-track.
4. Where the overhead structure is wider than 160', OCS support attachments or OCS poles under the bridge might be needed. Additional vertical clearance might be required to install OCS poles under overhead structures.
5. In cases where the vertical clearance is less than detailed above, the situation shall be evaluated on a case by case basis. The information needed for this evaluation is:

- Combined overhead structure and track plan view
- Overhead structure section elevation view with surveyed or planned clearance dimensions
- Overhead structure side elevation view with surveyed or planned clearance dimensions
- Details of bridge deck support beams or girders, and details of abutment or support columns, that may be used for OCS conductor support attachments

3.2.1.3.8 Grounding and bonding requirements

The 2x25 kV grounding and bonding network for the CHSTP is described in a separate document, namely the "CHSTP Grounding and Bonding" Technical Memorandum (TM 3.2.6). The grounding and bonding system shall provide for continuity of the traction return system to the ground busbars of the SSTs, SWSs and PSs sites via the track rails and static/ground conductors.

The overall grounding and bonding system includes aerial ground conductors, which shall be connected to the track via /impedance bonds and to any buried ground conductors or ground rods, and with connections to the ground busbars or ground grids at the SSTs, SWSs and PSs. In addition, the OCS grounding and bonding system shall inter-connect all non-live OCS metallic parts and bond reinforced concrete and metallic overhead structures.

The requirements of TES bonding and grounding applicable for the CHSTP OCS are described in Technical Memorandum 3.2.6 "TES Grounding and Bonding Requirements".

Additionally, under isolation conditions of a section of OCS, temporary grounding measures shall be put in place, such that both the catenary and the feeder wire are grounded so that maintenance can be carried out safely. The system used for grounding under isolation conditions shall protect maintenance personnel from electrical hazards, such as induction caused by adjacent OCS and high voltage power line crossings. Furthermore, these temporary grounding measures shall support full, short circuit loads in the event of the section becoming energized by incorrect closure of a switch(es) and/or circuit breaker(s) or by a pantograph "bridging" an insulated overlap or section insulator.

3.2.2 INTERFACE REQUIREMENTS

The main CHSTP technical interfaces which the Overhead Contact System shall satisfy are listed hereafter:

3.2.2.1 Traction Power Supply Interfaces

The main interfaces between the Overhead Contact System and the Traction Power Supply for the CHSTP are:

- Physical interface locations will be at the Traction Power Supply Stations (SST) that are connected to the HV Utility Supply and spaced approximately every 30 miles (48 km), at the Switching Stations (SWS) that are spaced approximately at mid distance between SSTs, i.e., at about 15 miles (24 km) from a SST, and at Paralleling Stations (PS) that are spaced approximately at 5 miles (8 km) intervals. At these Traction Power Supply Stations (TPSS) locations, aerial bare feeder conductors of adequate equivalent copper cross-section, together with feeding jumpers, will connect the 25 kV traction power busbars located within the TPSS site to the 25 kV catenary and its associated longitudinal 25 kV negative feeder. If the locations of the TPSS are not close enough to permit direct electrical connections to the catenary and its associated longitudinal negative feeder via aerial bare feeder conductors, insulated feeder cables will have to be dimensioned and run from the TPSS busbars in dedicated troughs and/or ducts along the track and up the OCS poles/structures where the electrical connections are to be made.

- Electrically, these interface points at SSTs, SWSs and PSs must be in accordance with the CHSTP Feeding and Sectionalizing Diagram that provides the locations of the TPSS Station sites, as well as the OCS sectionalizing information.
- In addition, the design and location of voltage transformers, which are to be installed on the Overhead Catenary System to monitor the voltage presence of each electrical section and sub-section, shall be interfaced with the Power Supply and SCADA (or equivalent data transmission system) to permit a satisfactory information monitoring management system.
- Based on the selected train characteristics and operating train traffic timetables (including the ultimate scenario), traction power simulations shall be carried out to demonstrate the adequacy of the traction power supply system configuration with final locations of SSTs, SWSs and PSs together with the voltage along the line, and to verify the design choice of transformer ratings and selected OCS conductor sizes. This design simulation exercise requires that train traffic timetables, train data, and power supply, OCS and return systems data be as exact as possible to permit precise analysis and best assessment of potential margins within the traction power supply system.
- The OCS voltage drop shall be in accordance with IEC 60850 "Supply voltages of traction systems", in which the main voltage criteria are as follow:
  - Operating nominal system voltage: 25.0 kV
  - Highest permanent voltage U_{max1}: 27.5 kV
  - Highest non-permanent voltage U_{max2}: 29.0 kV
  - Lowest permanent voltage U_{min1}: 19.0 kV
  - Lowest non-permanent voltage U_{min2}: 17.5 kV
- Short-circuits and other fault conditions occur and the power supply and electrification systems need to be designed so that the power supply controls detect these faults immediately and trigger measures to remove the short-circuit current and isolate the affected part of the circuit. After such events, the system has to be able to restore supply to all installations as soon as possible to resume operations. It should be noted that the electrical protection interfaces with the trains, and thus circuit breaker tripping in traction power substations and on the trains has to be coordinated. The maximum short circuit current shall be 12 kA for protection measurement purpose and accordingly for specification of the electrical equipment.

3.2.2.2 Signaling Interfaces

The main interfaces between the Overhead Contact System and the Signaling System for the CHSTP are:

- The OCS phase break arrangements, exact mileage locations and lengths, together with the locations of the associated signals (additional to the automatic track magnets) for opening and closing the train pantograph circuit breakers during pantograph passage through a phase break (generally located in front of the Switching Stations (SWS), and as required for operational and maintenance purpose in front of Traction Power Supply Stations (SST). Also, the Signaling System interfaces the power control at phase break locations with the Rolling Stock System.
- Signal Sighting to ensure that train driver visibility of trackside signals is not obstructed by OCS poles or other support structures or associated OCS equipment.
- The signaling speed diagram providing the start and finish mileages of the maximum speed at which trains can operate on the CHSTP alignment, both on sections dedicated to very high speed and in shared use corridors.
- The traction return current and the grounding and bonding system which includes the design principles, as well as the track connection (via impedance bonds) and buried ground conductor connections (with associated grounding plates), including details and locations.

- The signaling schemes, as well as signaling grounding and bonding diagrams to permit the correct interfacing of the above systems elements.

3.2.2.3 Civil Works and Track Interfaces

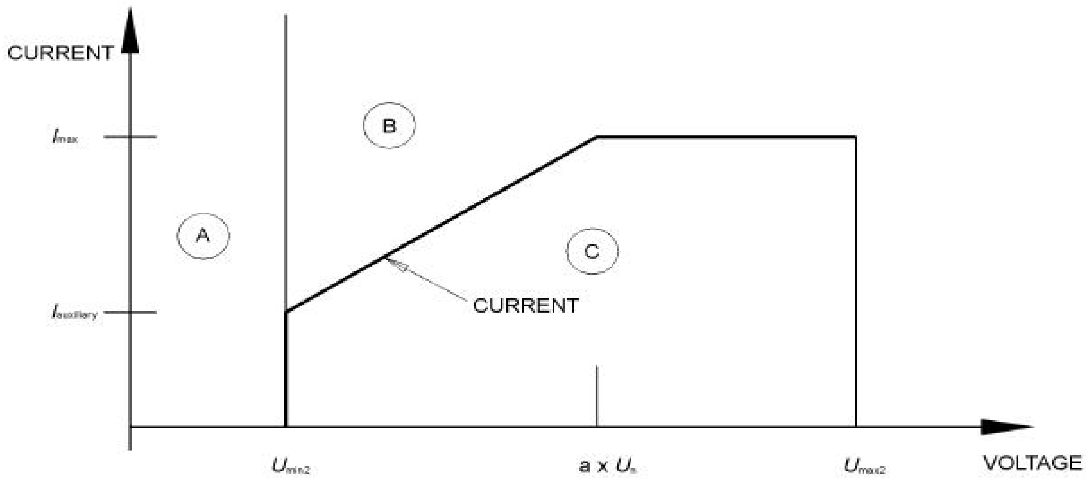
The main interfaces between the Overhead Contact System and the Track and Civil Works for the CHSTP are:

- Track alignment, providing along-track stationing data and route survey data, together with information regarding track curves, spirals and super-elevation necessary for the OCS basic and installation designs.
- Track cross-sections, including construction and maintenance tolerances, as well as details of track drainage, retaining walls, wind and sound walls, fencing, etc. as-built track information necessary for the design and installation of the OCS throughout the CHSTP alignment.
- Track alignment at OCS phase break locations, which shall preferably be located (as far as possible at these specific interface locations) on tangent track with no (or reduced) track gradient.
- Track turnout and crossover designs, and locations of turnout and crossover construction and maintenance areas, as needed to design and install specific OCS support and registration arrangements for the various types of track switches and crossings that would be used for the CHSTP, recognizing that single OCS pole construction may have to be replaced by overhead portal structures in these areas.
- Overhead bridge designs, including associated elevation and cross-section information, and construction tolerances, in sufficient detail to permit the design and installation of the OCS under the overhead bridges – the objective being to provide free-running arrangements with no OCS support or registration attachments on the bridge structures in sections of the CHSTP dedicated to very high speed.
- Tunnel, cut and cover structure and retaining wall designs, including construction tolerances, together with cross-section details, niches, tunnel lining and segments details, and cut and cover soffit and wall details, to which OCS equipment will be attached, preferably using either OCS anchor bolts or civil pre-installed C-channels, all as needed for the design and installation of the OCS on or through these structures.
- Underbridge and viaduct designs, including construction tolerances, together with cross-section details, OCS structure fixing arrangement details (preferably using civil manufactured bases with anchor bolts) necessary for the design and installation of the OCS on viaducts and underbridges.
- Geotechnical information, providing soil type information, lateral bearing pressures and vertical bearing pressures, together with soil resistivity values, which will permit the designer to precisely size, calculate and further allocate the different types of OCS pole foundations that will, in general, be located between 10 ft and 14 ft from track centerline.
- Passenger station platform designs, including construction tolerances, together with cross-section details, as needed for the design and installation of the OCS structures and wiring arrangements in the station platform areas.
- Designs for along-track fences, wind and sound walls, and any other civil structures that are to be installed within the right-of-way fenced limits, including construction tolerances, together with cross-sections and other relevant details including gates, barriers, which are needed for the development of grounding and bonding continuity designs for these elements, and for integration with the design and installation of the grounding and bonding associated with the OCS.

3.2.2.4 Rolling Stock Interfaces

The main interfaces between the Overhead Contact System and the Rolling Stock for the CHSTP are:

- The manufacturer's rolling stock static and dynamic gauges of the trains that will be operated on the electrified tracks of the CHSTP, which are required for the OCS design, particularly for setting up (or confirming) the contact wire heights on the sections dedicated to very high speed operation and on shared use corridors.
- The maximum allowable train rated current (600A for 25 kV ac systems) and the train current graph as a function of the OCS line voltage, as per the figure below:



I_{max}= maximum current consumed by the train

A= no traction

B= current level exceeded

C= allowable current levels

Graph of the maximum train current against voltage

Note: Trains shall be equipped with an automatic device that adapts the level of the power consumption depending on the OCS line voltage in steady state conditions.

- The pantograph operating height range, e.g., the minimum and maximum operating heights of the pantograph.
- The pantograph dimensions and physical characteristics which are necessary to confirm the pantograph clearance envelopes that are required for design and for testing of the overhead contact system. Refer to the CHSTP "Pantograph Clearance Envelopes" Technical Memorandum (TM 3.2.3). Note: only one type of pantograph is to be used for the CHSTP.
- The number of pantographs in service per train and the pantograph spacing (e.g., 656 feet [200 m]) which are necessary to confirm the OCS phase break design arrangements, and which have a fundamental impact on the quality of current collection, since the dynamic effects of each pantograph can interfere with others on the OCS.
- The pantograph model and the pantograph static and dynamic characteristics, which are necessary to simulate the pantograph OCS dynamic interaction at high speed in order to ensure, at the design stage, that there will be minimum interruption of contact continuity between the rolling stock pantograph collectors and the overhead contact system, as required for good system performance and to better assess the contact system maximum uplift. As previously stated, the static force shall be adjustable between 9 and 27 pounds force (40 and 120 N) and the nominal static force is to be 15.75 (+4.5/-2.25) pounds force (70

+20/-10 N). Only pantographs designed and proven for very high speed performance shall be considered for the CHST.

- The pantographs details including the nature of the contact strip material to confirm its compatibility with the contact wire regarding limitation of wear on both components.
- Additional pantographs features, namely a safe dropping device (e.g., a device that drops the pantograph automatically to ensure the protection of the pantograph and overhead contact line equipment in case of a pantograph failure), a pantograph uplift limiting device in order to minimize risks, at very high speed, of abnormal excessive uplift resulting in bad current collection and possible damage, and insulated horns that are recommended so as to reduce the overall electrical clearance envelope around the dynamic pantograph gauge.

3.2.2.5 Interface with the Electrical Operational Control Center and DTN / SCADA System

These interfaces concern the OCS electrical equipment (circuit breakers, motor-operated disconnect switches and isolators, as well as voltage transformers, etc.), which are monitored and command-controlled from the Electrical Operational Control Center via the Data Transmission Network (DTN) / Supervisory Control and Data Acquisition (SCADA) system.

The interface between the OCS electrical equipment and the Electrical Operational Control Center is to ensure:

- That the power supply and OCS main electrical equipment, as indicated on the relevant Power Supply Feeding and Sectionalizing diagrams, are correctly displayed at the Electrical Operational Control Center.
- That the monitoring information and alarm status, and command-control operations, and status reporting, regarding the OCS electrical equipment, are effectively taken into account by the Electrical Operational Control Center.
- A successful energization process during the testing and commissioning phase.
- That Emergency isolation and Routine (maintenance) isolation processes of the OCS are correctly taken into account and operated satisfactorily.

The interface between the OCS electrical equipment and the DTN / SCADA is to:

- Provide as requested by the designer of the DTN / SCADA system, all the equipment information necessary to ensure satisfactory monitoring and command-control operation and status reporting of the OCS electrical equipment.
- Ensure compatibility with the DTN / SCADA system, regarding the number and type of contacts, and physical connections at each type of OCS electrical equipment to correctly interface with the DTN / SCADA system.
- Verify that the DTN / SCADA system at OCS equipment locations and remote unit locations successfully transfers the information necessary for the satisfactory monitoring and command-control operation and status reporting of the OCS electrical equipment.

3.2.3 CONSTRUCTION REQUIREMENTS, TESTING AND COMMISSIONING REQUIREMENTS

3.2.3.1 Construction Requirements

3.2.3.1.1 Construction Design

To ensure that the OCS will be correctly installed in accordance with the requirements for the operation of high speed trains, with a high level of Quality Assurance in compliance with the policies, processes and programs required for the CHSTP, it will be necessary to produce a complete OCS detailed design, including construction phasing in advance of the planned installation.

The OCS construction design shall consist of detailed OCS layouts, OCS cross-section/data sheets, OCS foundation designs, longitudinal auxiliary conductor profiles, OCS hanger tabulations, OCS calculations for foundations, poles and cantilever arrangements, installation details for switching arrangements, and OCS under bridge (or other structure) arrangements, as well as all the necessary detailed bills of quantities.

This OCS construction design shall be revised as necessary during the construction phase and be updated as needed to provide an as-built record shortly after completion of construction.

3.2.3.1.2 Requirements for the OCS construction

The OCS construction shall be carried out in accordance with a CHSTP OCS Construction Plan which shall demonstrate that, during the construction phase, the OCS technical and safety requirements of the CHSTP will be met with high Quality Assurance, in accordance with the policies, processes and programs required for the CHSTP, and as necessary to provide an OCS suitable for high speed train operations.

Detailed OCS construction programs interfacing with other works shall be produced and monitored on a weekly and monthly basis to ensure that the OCS program of works is well managed and well integrated within the overall CHSTP program of works, and that the works are carried out in accordance with the program.

OCS works shall be in carried out in accordance with technical construction method statements, providing detailed information on the organization, safety, utilized plant and personnel resources, together with the operating methods for the works and necessary checks (witness and eventual hold points) required to confirm the quality of the installation works.

Installation tolerances for high-speed train operations are very restrictive, and the OCS equipment shall be installed in accordance with these tight tolerances to ensure that the catenary components including the contact wire are installed as required to provide satisfactory current collection at high-speed and very high-speed.

3.2.3.2 Testing and Commissioning Requirements

The OCS Testing and Commissioning shall be carried out in accordance with a CHSTP OCS Testing and Commissioning Plan which shall demonstrate that, through the testing and commissioning phases, the necessary OCS technical requirements of the CHSTP and requirements for a high speed OCS will be met with high Quality Assurance, in accordance with the policies, processes and programs required for the CHSTP.

The OCS Testing and Commissioning shall be carried out in phases to ensure:

- quality surveillance of procured equipment, including factory acceptance of materials and OCS components,
- technical verification and static testing to confirm the correct installation of the OCS,
- integrated testing of the OCS with other disciplines, including energization of the OCS and short circuit testing,

- dynamic testing of the OCS,
- surveillance when trains are running during the period following dynamic testing and during the first weeks of driver-training operation of the line, prior to service operation of the line,.

The dynamic testing of the OCS is of primary importance for high-speed train operations to verify the interaction between the overhead contact system and the pantograph, and thus the safety and quality of the current collection and the performance of the OCS at high-speed.

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

- the percentage of arcing, and the contact force
- the contact wire uplift at the supports as the pantograph passes.

Concerning the measurement of arcing, the arc detector shall be sensitive to the wavelengths of light emitted by copper materials. For copper and copper alloy contact wires, the wavelength ranges include a range 220 nm to 225 nm, and from 323 nm to 329 nm. The measurement system shall be insensitive to visible light with wavelengths greater than 330 nm.

The measurement of contact force shall be carried out using an instrumented pantograph equipped with force sensors located as near as possible to the contact points. The measurement system shall be immune to electromagnetic interference, and shall measure forces in the vertical direction, without interference from forces in other directions. The measurement deviation of the force sensors caused by temperature changes shall be less than 2.25 pounds force (10 N) for the sum of the force of all sensors under all measuring conditions, and the maximum error of the measurement system shall be less than 10 %.

During OCS dynamic testing of a section not shorter than 6 miles (9.7 km), the following measurements of the system, as a minimum, shall be recorded:

- the pantograph current (measured values with a pantograph current less than 30% of the nominal current of the pantograph shall be disregarded),
- the total time with a pantograph current greater than 30% of the nominal current per train per pantograph,
- the total run time,
- the number of arcs that last longer than 1 ms (arcs of durations shorter than or equal to 1 ms shall be disregarded),
- the duration of each arc longer than 1 ms (the along-track stationing of the arc on overhead contact line shall also be recorded),
- the largest arc duration, and
- the sum of the durations of all arcs longer than 1 ms.

In addition to the measured values, the operating conditions (alomg-track train location and train speed which shall be constant within a tolerance of ± 1.5 mph, etc.) shall be recorded continuously, together with the environmental conditions (rain, ice, temperature, wind, tunnel, etc.), and test configuration (parameters and arrangement of pantographs, type of overhead contact system, etc.) that apply during the measurement period shall be recorded in the test report. This additional information shall permit repeatability of testing and measurements to facilitate comparisons between the results of different tests.

4.0 SUMMARY AND RECOMMENDATIONS

- The CHSTP Overhead Contact System shall permit a maximum operational speed of 125 mph (200 km/hr) in shared use corridors where high-speed passenger trains and American passenger trains operate on the same main line shared tracks.
- Elsewhere, on dedicated high-speed sections, the CHSTP Overhead Contact System shall permit a maximum operational speed of 220 mph (354 km/hr) with consideration that faster operation will not be unnecessarily precluded in the future.
- The CHSTP OCS shall be electrically divided into electrical sections and sub-sections. On the main line, Phase Break separations and Insulated Overlaps only shall be used for sectionalizing purposes.
- Elsewhere, on diverted tracks and stabling tracks, Section Insulators performing at speeds up to 125 mph (200 km/hr) would be acceptable in lieu of insulated overlaps for sectionalizing purposes.
- Electric trains shall be able to go through the phase break arrangement without establishing an electrical continuity between the successive electrical sections which are fed from different phases. This shall be realized at the maximum operating speed and with the train pantographs raised and in contact with overhead catenary, but with the pantograph breaker off.
- On the CHSTP sections dedicated to very high speed, either a phase break design of at least 1319 feet long, or a shorter phase break separation of less than 466 feet long constituted by three insulated overlaps can be used. Adequate means shall be provided to allow a train that is stopped within the above phase break arrangements to be restarted; i.e. the neutral section shall be connectable to the adjacent sections by remotely controlled switches/isolators.
- On shared use corridors where the maximum operation speed is 125 mph (200 km/hr), the designs of phase break separation sections for high speed sections can be adopted, but in addition, a third phase break design arrangement of an overall distance less than 27 feet using insulators and having its centre section connected to the current return path / ground may also be adopted.
- The design of the OCS phase break arrangement shall be interfaced with the rolling stock (for the number and for the spacing of pantographs which shall be 656 feet) and the signaling (for the exact mileage locations and lengths of the OCS phase break arrangements).
- Concerning the high speed overhead contact system / pantograph interaction, only pantographs designed and proven for very high speed performance shall be considered for the CHST.
- For the CHST, there should be only one type of pantograph current collector head used for all trains and carbon strip material is recommended to minimize wear.
- For the CHST, the pantograph static force shall be adjustable between 9 and 27 pound force (40 and 120 N) and the nominal static force is to be 15.75 (+4.5,-2.25) pound force (70 N + 20 N/-10 N).
- The CHST pantograph shall be equipped with a fail safe device that will detect any failures of the contact strips and will trigger the lowering of the pantograph in case of a failure.
- The current collection at the design stage shall be assessed at the maximum operational speeds, by the determinations of the mean value (Fm), of the standard deviation (σ) of simulated contact forces, of the statistical value $F_m - 3\sigma$, of the contact loss percentage (NQ), and of the vertical movement of the contact point.
- The design performance of the CHSTP high speed OCS shall allow guarantee and demonstration of a very high level of Reliability, Availability, Maintainability and Safety through a RAMS analysis.
- In order to ensure that the CHSTP catenary system will have a known and proven dynamic behavior that will make it suitable for an operational speed up to 220 mph (354 km/hr) on sections dedicated to very high speed and up to 125 mph (200 km/hr) on shared use corridors, the catenary characteristics including those of the contact and messenger wires and of their mechanical tensions, together with the droppering system shall be those of an existing proven high speed overhead contact system.
- The CHSTP OCS shall preferably consists of a simple auto-tensioned catenary system using a bare bronze or other copper alloy messenger wire supporting a solid pre-sagged copper (or copper alloy)

contact wire, by means of copper alloy current carrying dropper (ensuring no "hard spot" on the contact wire and providing the correct contact wire profile for high-speed current collection), an aerial negative longitudinal feeder, and an aerial ground wire, connecting each OCS supporting structure.

- In the sections dedicated to very high speed, tunnels should be of sufficient area so as to permit installation of bare feeder wires. However, in the shared use corridors, tunnels of smaller sections would necessitate installation of pull off only reduced system height equipment and would not permit installation of bare longitudinal feeder. Insulated feeder cables would have to be used in lieu of bare feeder conductors.
- The overhead contact system shall be free running under overhead bridges. New bridges shall therefore be designed to accommodate a free height clearance. On dedicated shared use corridors, existing bridge height clearances shall be reviewed so as to accommodate free running OCS as well.
- The contact wire shall be installed and maintained at a nominal constant and minimum 17'-4.7"(5300mm). height at support all along the sections dedicated to very high-speed where the maximum vehicle static gauge height will be 14 ft 9 ¼ in accordance with the ''Structure Gauge'' technical Memorandum. Also, the height difference at each adjacent structure is to be less than 1/2 in so as to ensure a constant contact wire height as required for satisfactory pantograph current collection at high-speed.
- On shared use corridors where high-speed vehicles will share the track with other American passenger cars of a maximum vehicle static gauge height of 17 ft in accordance with the ''Structure Gauge'' Technical Memorandum, and where the maximum operating speed is 125 mph (200 km/hr), the contact wire height shall generally be set up at a height 18'-8.4"(5700 mm) at support.
- The contact wire height transition between sections dedicated to very high-speed and shared use corridors shall be realized in areas where the speed does not exceed 125 mph (200 km/hr). The maximum contact wire gradients and the corresponding maximum gradient changes shall not exceed, according to the maximum speed, the following values:

Maximum speed	Maximum contact wire gradient	Maximum contact wire gradient change
> 125 mph	0	0
125 mph	2/1000	1/1000
100 mph	3.3/1000	1.7/1000
75 mph	4/1000	2/1000
60 mph	6/1000	3/1000
45 mph	8/1000	4/1000
30 mph	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. The stagger shall normally be set at ±8 in. On curved track, the staggers shall be calculated on a case by case basis taking into account the track cant, radius track curvature, and wind speed.
- The method of auto-tensioning the messenger and contact wire conductors shall be by balance weight arrangements using tensioning devices. For very high speed, the tensions are to be applied to the contact and messenger wires individually by using separate balance weights, tensioning devices and anchoring positions. For speeds up to 125 mph (200 km/hr) in the shared use corridors, the messenger and contact wires will be auto-tensioned using one common balance weight arrangement and a yoke plate.
- The CHSTP Overhead Contact System shall ensure reliable operation under the environmental and climatic conditions given in section 3.2.1.3.3 and the mechanical tension in each of the contact and messenger wires shall be automatically maintained over a 25^{o}F to 176^{o}F temperature range in above grade sections, while after the first 1300 ft in tunnels, the temperature range for auto-tensioning the conductors shall be 35^{o}F to 155^{o}F.
  - For OCS design, the operational wind speed (used to compute catenary support, catenary wire displacement for pantograph security and maximum span length calculations) should be taken as Vop = 60 mph, and the design wind speed (used to determine the ultimate strength requirements of the

OCS) should be taken as Vbws = 85 mph corresponding to the ASCE and NESC basic wind speed for the CHSTP route.

- The wind velocity pressure qz shall be calculated by the NESC formula:

  $q_z = 0.00256\ V^2\ K_z\ G_{RF}\ \mathbf{I}\ C_f\ A$ in lb/sq ft (equivalent to $q_z = 0.613\ V^2\ K_z\ G_{RF}\ \mathbf{I}\ C_f\ A$ in N/m^2)

- Loads due to wind for OCS structural calculations shall be multiplied by the load factors given by table 253-1 of the NESC.
- Maximum tension lengths from anchor to anchor shall not exceed 4000 ft in tunnels and in front of power supply stations and 4600 ft in open route. Exceptionally for a specific case, a tension length of up to 5000 ft may be found acceptable. At approximately mid-distance between auto-terminated anchors, mid-point arrangements shall be installed such that maximum half tension lengths do not exceed 2000 ft in tunnels and 2300 ft in open route.
- The OCS static and dynamic electrical recommended clearance values to be used for the CHSTP are:

Clearances	For CHST sections dedicated to very high speed		For shared use corridors for speeds up to 125 mph (200 km/hr)	
	Static (in)	Dynamic (in)	Static (in)	Dynamic (in)
Normal	1'-0.6" (320mm)	8.7" (220mm)	1'-0.6" (320mm)	8.7" (220mm)
Minimum	1'-0.6" (320mm) .	8.7" (220mm)	10.6" (270mm)	6.7" (170mm)

- For pantograph security purposes, the permissible lateral deflection of the contact wire under the action of crosswind shall be ≤ 15 ¾".
- At the maximum operational speed, the dynamic pantograph envelope shall consider twice the value of the estimated or simulated uplift S_0 at the support point, i.e. 9.8"(250 mm) minimum. In very high speed dedicated sections, the design of the OCS cantilever and registration shall consequently allow for a steady arm uplift clearing at least the dynamic pantograph envelope, and thus allow for a minimum uplift of 9.8"(250 mm).
- In shared use corridors where the maximum operational speed is 125 mph (200 km/hr), the design of the OCS cantilever and registration shall allow for a steady arm uplift clearing at least the dynamic pantograph envelope for such speed, and thus allow for a minimum uplift of 7.9"(200 mm).
- The above grade sections' OCS structures are to be galvanized Universal Column (U.C.)/H-beams and are to be designed and manufactured to the relevant steel standards.
- The OCS supporting structures shall be calculated in accordance with relevant American standards (NSCE, ASCE, ANSI) and in addition, the maximum mast deflection across track, including wind and ice loading, is not to exceed two (2) inches at contact wire level.
- Where the OCS is closely supported in above grade sections, such as at overlaps and turnouts, multiple cantilevers will be attached to a single structure of a heavier section as the applied loads shall not cause twisting of the structure by more than five (5) degrees.
- For multi track areas when independent masts 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, to equip maintenance yard multi track areas or in shared use corridors such as at passenger stations approach, headspans arrangement may be used if considerations dictate.

- In tunnels and cut and covers, or for wall fixings, galvanized steel supports shall be fixed using either C-channels or anchor expansion bolts of the undercut type.
- Each and every OCS support location shall be individually numbered for ease of identification on site.
- The overall 2x25 kV grounding and bonding protection network for the CHSTP shall consist of OCS aerial ground conductors, connections from these aerial ground conductors to the general buried ground conductor/grounding pillars/impedance bonds connected to the track and connections between all the later and the SSTs, SWSs and PSs grounding bars.
- In addition, the OCS grounding and bonding system shall safely connect all OCS metallic non live parts and also safely bond overhead bridges.
- The bonding and grounding of the OCS and of other lineside equipment shall ensure, in accordance with IEC 479-1 that the touch potentials are not exceeding:
  - 60 V where accessible to the public under all power supply feeding conditions
  - 650 V for less than 200 ms under short circuit conditions.
- The OCS voltage drop shall be in accordance with IEC 60850 “Supply voltages of traction systems”, whose main voltage criteria are as follow:
  - Operating nominal system voltage: 25.0 kV
  - Highest permanent voltage U_{max1}: 27.5 kV
  - Highest non-permanent voltage U_{max2}: 29.0 kV
  - Lowest permanent voltage U_{min1}: 19.0 kV
  - Lowest non-permanent voltage U_{min2}: 17.5 kV
- In addition, the maximum short circuit current shall be 12kA for protection measurement purpose and accordingly for specification of the electrical equipment.
- The design and locations of voltage transformers that shall be installed on the Overhead Catenary System to monitor the voltage presence of each electrical section and sub-section shall be interfaced with the Power Supply and SCADA (or equivalent data transmission system) and Signaling to permit a satisfactory information monitoring management system.
- The OCS and the signaling systems shall interface:
  - the phase break separation together with the Civil Work (so as to ensure no or reduced track gradient at the phase break location) and the Traction Power Supply, for the exact mileage locations and lengths of the OCS phase break arrangements together with the locations of the associated signaling equipment.
  - the signaling visibility in order that trackside signals are not obstructed to train driver visibility by OCS masts and associated OCS equipment.
  - the traction return current and the grounding and bonding system which includes the design principles, as well as the signaling schemes, including the track connection (via impedance bonds) and buried ground conductor connections (with associated grounding plates), including details and locations.
- The Civil Work infrastructure shall interface with the OCS:
  - the design, construction tolerances and as built information of the track platforms and associated cross-sections including details and as-built information of track drainage, retaining walls, wind and sound walls, fencing, etc necessary to design and install the OCS in open route.
  - the design, construction tolerances and as-built information of tunnels alignment together with cross-section details, niches, lining and segments details to which OCS equipment will be fixed.
  - the track alignment at OCS phase break locations so as to ensure no (or reduced) track gradient at the phase break location.
  - the track alignment providing all information related to track curves, spirals and superelevation necessary for the OCS basic and installation designs.

- the track construction and maintenance tolerances, as well as the as-built track information necessary to design and install the OCS all along the CHSTP alignment.
- the track turnout and crossover designs and as-built information necessary to design and install the specific OCS arrangements to the different type of points and crossings that would be used for the CHSTP.
- the design, construction tolerances and as-built information of the overhead bridges and associated elevation and cross-section information including details necessary to design and install the OCS (free running in sections of the CHSTP dedicated to very high speed) under overhead bridges.
- the design and as-built information of underbridges and viaducts together with cross-section details, OCS masts fixing arrangement details (preferably using civil manufactured bases with anchor bolts) and as-built information necessary to design and install the OCS on viaducts and underbridges.
- the dimensions and locations of the turnout and crossover construction and maintenance areas.
- the geotechnical information providing ground pressure values related to the platform ground and permitting to precisely size, calculate and further allocate the different types of OCS mast foundations (basically located between 10 ft and 14 ft from the closest track centerline).
- the alignment and platform surveys.
- the grounding and bonding continuity of alongside fences, wind and sound walls, gates, barriers and any other civil structures installed within the right-of-way fenced limits.

- The Rolling Stock shall interface with the OCS:
  - the manufacturer rolling stock static and dynamic gauges of the trains that will be operated on the electrified tracks of the CHSTP and which are required for the OCS design
  - the maximum allowable train rated current (600A for 25 kV AC systems) and the train current graph as a function of the OCS line voltage.
  - the pantograph reaching height, e.g. the minimum and maximum operating heights of the pantograph.
  - the pantograph (i.e. there should be only one type of pantograph used on the CHST) dimensions and physical characteristics which are necessary to confirm the pantograph clearance envelopes which are required for design and for testing of the overhead contact system.
  - the number of pantographs in service per high-speed train and their spacing (e.g. 656 feet).
  - the pantograph model and the pantograph static and dynamic characteristics. Only pantographs designed and proven for very high speed performance shall be considered for the CHST.
  - the pantographs details including the nature of the contact strip material.
  - the existence of additional pantographs features, namely a safe dropping device, a pantograph's uplift limiting device (pantograph stop), and insulated horns.
- The OCS and the Electrical Operational Control Center shall interface all the relevant design information related to OCS electrical equipment consisting of motorized breakers/switches, isolators, voltage transformers, etc.
- The OCS and the Data Transmission Network / SCADA shall interface all the relevant design information related to the monitoring and control-command operation and status of OCS electrical equipment.
- The OCS construction design shall consist of detailed OCS layouts, OCS cross-section/data sheet books, OCS footing books, longitudinal auxiliary conductor profiles, OCS special droppering books, OCS calculations books for footings, masts and cantilever arrangements, detailed installation books for individual switching arrangements and OCS under bridge (or other structure) arrangements, as well as all the necessary detailed bill of quantities.

- The OCS construction design shall be revised as necessary during the construction phase and be updated as an as-built record shortly after construction.
- The OCS construction shall be carried out in accordance with a CHSTP OCS Construction Plan which shall demonstrate that, during the construction phase, the OCS technical and safety requirements of the CHSTP will be met in accordance with the high Assurance Quality policy, process and program required for the CHSTP, and necessary for OCS high speed.
- Detailed OCS construction programs interfacing with other works shall be produced and monitored on a monthly and weekly basis to ensure that the OCS program of works is well managed and well integrated within the overall CHSTP program of works, and that the works are carried out in accordance with the program.
- OCS works shall be in carried out in accordance with technical construction method statements providing detailed information on the organization, safety, utilized plant and personnel resources, together with the operating methods of the works and necessary checks (witness and eventual hold points) required to confirm the quality of the installation works.
- Installation tolerances for high-speed are very restrictive, and the OCS equipment shall be installed in accordance with these tight tolerances to ensure that the catenary components including the contact wire are installed as required for a satisfactory current collection at high speed and very high speed.
- The OCS Testing and Commissioning shall be carried out in accordance with a CHSTP OCS Testing and Commissioning Plan which shall demonstrate that, through the testing and commissioning phases, the necessary OCS technical requirements of the CHSTP will be met in accordance with the high Assurance Quality policy, process and program required for the CHSTP, and necessary for OCS high speed.
- The OCS Testing and Commissioning shall be carried out in phases to ensure:
  - the quality surveillance of procured equipment, including factory acceptance of materials and OCS components,
  - the technical verifications and static tests to confirm the correct installation of the OCS,
  - the integrated testing of the OCS with other disciplines, including the OCS energization and short circuit tests,
  - the dynamic testing of the OCS,
  - the surveillance when trains are running during the period following the dynamic testing and prior to the operation and the line, and during the first weeks of the operation of the line.
- The dynamic performance capability of the OCS current collection system shall be checked as part of the dynamic testing, and at least the following data shall be measured:
  - the percentage of arcing, and additionally the contact force,
  - the contact wire uplift at the support as the pantograph passes.
- Also, during the OCS dynamic tests, the following shall be measured and recorded:
  - the pantograph current (measured parts with a pantograph current below 30% of the nominal current of the pantograph shall be disregarded),
  - the total time with a pantograph current greater than 30% of the nominal current per train per pantograph,
  - the total run time,
  - the number of arcs that are lasting longer than 1 ms (as arcs of a duration shorter or equal to 1ms shall be disregarded),
  - the duration of each arc longer than 1 ms (the mileage position of the arc along the overhead contact line should also be recorded),
  - the largest arc duration, and
  - the sum of the durations of all arcs longer than 1 ms.

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
- UIC 606-1 OR
- The Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA Manual)
- Amtrak guidelines and present practices
- OCS Standard Drawings

6.0 DESIGN MANUAL CRITERIA

- Electric trains shall be able to go through the OCS phase break arrangement without establishing an electrical continuity between the successive electrical sections which are fed from different phases. This shall be realized at the maximum operating speed and with the train pantographs raised and in contact with overhead catenary, but with the pantograph breaker off.
  - On the CHSTP sections dedicated to very high speed, either a phase break design of at least 1319 feet long, or a shorter phase break separation of less than 466 feet (142 m) constituted by three insulated overlaps can be used. Adequate means shall be provided to allow a train that is stopped within the above phase break arrangements to be restarted; i.e. the neutral section shall be connectable to the adjacent sections by remotely controlled switches/isolators.
  - On shared use corridors where the maximum operation speed is 125 mph (200 km/hr), the designs of phase break separation sections for high speed sections can be adopted, but in addition, a third phase break design arrangement of an overall distance less than 27 feet using insulators and having its centre section connected to the current return path / ground may also be adopted.
- For the CHST, there should be only one type of pantograph current collector head used for all trains and carbon strip material is recommended to minimize wear. The pantograph static force shall be adjustable between 9 and 27 pound force (40 and 120 N) and the nominal static force is to be 15.75 (+4.5,-2.25) pound force (70 N + 20 N/-10 N). The CHST pantograph shall be proven for very high speed performance and equipped with a fail safe device that will detect any failures of the contact strips and will trigger the lowering of the pantograph in case of a failure. Also the CHST pantograph shall be equipped with an uplift limiting device (pantograph stop) and with insulated horns.
- The OCS-pantograph current collection at the design stage shall be assessed at the maximum operational speeds, by the determinations of the mean value (Fm), of the standard deviation (σ) of simulated contact forces, of the statistical value $F_m – 3\sigma$, of the contact loss percentage (NQ), and of the vertical movement of the contact point.
- The CHSTP OCS shall preferably consists in a simple auto-tensioned catenary system using a bare bronze or other copper alloy messenger wire supporting a solid pre-sagged copper (or copper alloy) contact wire, by means of copper alloy current carrying dropper, an aerial negative longitudinal feeder and an aerial ground wire connecting each OCS supporting structure.
- The contact wire shall be installed and maintained at a nominal constant and minimum 17'-4.7"(5300 mm) height at support all along the sections dedicated to very high-speed and the height difference at each adjacent structure is to be less than 1/2 in. so as to ensure a constant contact wire height required for satisfactory pantograph current collection at high-speed.
- On shared use corridors where high-speed vehicles operate on tracks shared with American passenger cars, the contact wire height shall generally be set up at a height 18'-8.4"(5700 mm) at support.
- The contact wire height transition between sections dedicated to very high-speed and shared use corridors shall be realized in areas where the speed does not exceed 125 mph (200 km/hr). The maximum contact wire gradients and the corresponding maximum gradient changes shall not exceed, according to the maximum speed, the following values:

Maximum speed	Maximum contact wire gradient	Maximum contact wire gradient change
> 125 mph	0	0
125 mph	2/1000	1/1000
100 mph	3.3/1000	1.7/1000
75 mph	4/1000	2/1000
60 mph	6/1000	3/1000
45 mph	8/1000	4/1000
30 mph	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. The stagger shall normally be set at ±8 in. On curved track, the staggers shall be calculated on a case by case basis taking into account the track cant, radius track curvature, and wind speed.
- The method of auto-tensioning the messenger and contact wire conductors shall be by balance weight arrangements using tensioning devices. For very high speed, the tensions are to be applied to the contact and messenger wires individually by using separate balance weights, tensioning devices and anchoring positions, while for speeds up to 125 mph (200 km/hr) in the shared use corridors, the messenger and contact wires will be auto-tensioned using one common balance weight arrangement and a yoke plate.
- The CHSTP Overhead Contact System shall ensure reliable operation under the California specified environmental and climatic conditions and the mechanical tension in each of the contact and messenger wires shall be automatically maintained over a 25^{o}F to 176^{o}F temperature range in above grade sections, while after the first 1300 ft in tunnels, the temperature range for auto-tensioning the conductors shall be 35^{o}F to 155^{o}F.
- For OCS design, the operational wind speed is Vop = 60 mph, and the design wind speed is Vbws = 85 mph. The wind velocity pressure qz shall be calculated by the NESC formula: $q_z = 0.00256\ V^2\ K_z\ G_{RF}\ I\ C_f\ A$ in lb/sq ft (equivalent to $q_z = 0.613\ V^2\ K_z\ G_{RF}\ I\ C_f\ A$ in N/m^2), and the loads due to wind for OCS structural calculations shall be multiplied by the load factors given by table 253-1 of the NESC.
- For pantograph security purposes, the permissible lateral deflection of the contact wire under the action of crosswind shall be ≤ 15 ¾".
- Maximum tension lengths from anchor to anchor shall not exceed 4000 ft in tunnels and in front of power supply stations and 4600 ft in open route.
- The overhead contact system shall be free running under overhead bridges.
- The OCS static and dynamic electrical recommended clearance values to be used for the CHSTP are:

Clearances	For CHST sections dedicated to very high speed		For shared use corridors for speeds up to 125 mph (200 km/hr)	
	Static (in)	Dynamic (in)	Static (in)	Dynamic (in)
Normal	1'-0.6" (320mm)	8.7" (220mm)	1'-0.6" (320mm)	8.7" (220mm)
Minimum	1'-0.6" (320mm)	8.7" (220mm)	10.6" (270mm)	6.7" (170mm)

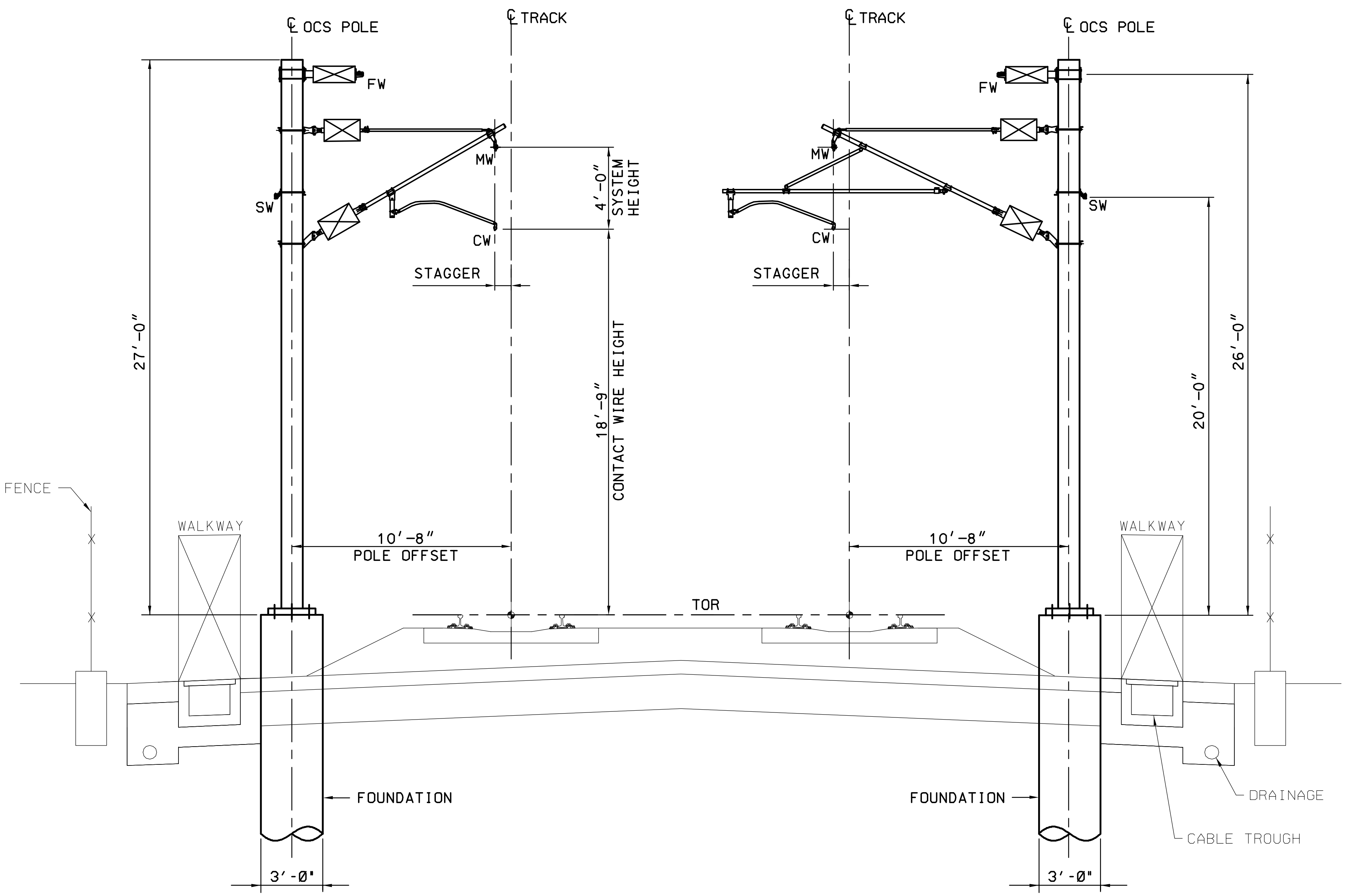
- At the maximum operational speed, the dynamic pantograph envelope shall consider twice the value of the estimated or simulated uplift S_0 at the support point, i.e. 9.8" (250 mm) minimum. In very high speed dedicated sections, the design of the OCS cantilever and registration shall consequently allow for a steady arm uplift clearing at least the dynamic pantograph envelope, and thus allow for a minimum uplift of 9.8"(250 mm).
- In shared use corridors where the maximum operational speed is 125 mph (200 km/hr), the design of the OCS cantilever and registration shall allow for a steady arm uplift clearing at least the dynamic pantograph envelope for such speed, and thus allow for a minimum uplift of 7.9"(200 mm).
- The above grade sections' OCS structures are to be galvanized Universal Column (U.C.)/H-beams and are to be designed and manufactured to the relevant steel standards.

- The OCS supporting structures shall be calculated in accordance with relevant American standards (NSCE, ASCE, ANSI) and the maximum mast deflection across track, including wind and ice loading, is not to exceed two (2) inches at contact wire level.
- Where the OCS is closely supported in above grade sections, such as at overlaps and turnouts, multiple cantilevers will be attached to a single structure of a heavier section as the applied loads shall not cause twisting of the structure by more than five (5) degrees.
- For multi track areas when independent masts cannot be installed between tracks, portal structures using drop tubes permitting to maintain mechanical independence of the equipment related to individual tracks, are to be designed with respect to overall aesthetics of the complete OCS.
- In tunnels and cut and covers, or for wall fixings, galvanized steel supports shall be fixed using either C-channels or anchor expansion bolts of the undercut type.
- Each and every OCS support location shall be individually numbered for ease of identification on site.
- The overall 2x25 kV grounding and bonding protection network for the CHSTP shall consist of OCS aerial ground conductors, connections from these aerial ground conductors to the general buried ground conductor/grounding pillars/impedance bonds connected to the track and connections between all the later and the SSTs, SWSs and PSs grounding bars. In addition, the OCS grounding and bonding system shall safely connect all OCS metallic non live parts and also safely bond overhead bridges.
- The bonding and grounding of the OCS and of other lineside equipment shall ensure, in accordance with IEC 479-1 that the touch potentials are not exceeding:
  - 60 V where accessible to the public under all power supply feeding conditions
  - 650 V for less than 200 ms under short circuit conditions.
- The OCS voltage drop shall be in accordance with IEC 60850 "Supply voltages of traction systems", whose main voltage criteria are as follow:
  - 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 shall be 12kA for protection measurement purpose and accordingly for specification of the electrical equipment.
- OCS voltage transformers shall be installed on the Overhead Catenary System to monitor the voltage presence of each electrical section and sub-section.
- In addition to the pantograph envelope indicated in TM 3.2.3, the minimum vertical clearance of the overhead structure shall also consider the vertical clearance between the energized parts of OCS and the feeder cable when the feeder cable is located at track side and is supported by the same structure as indicated in the directive drawings. The required vertical clearance for new structures without OCS conductor support attachments is 27'. The required vertical clearance for existing structures without OCS conductor support attachments is 24'. These clearances assume the overhead structures are no more than 160' wide. Where the overhead structure is wider than 160', OCS support attachments or OCS poles under the bridge might be needed. Additional vertical clearance might be required to install OCS poles under overhead structures.
- The dynamic performance capability of the OCS current collection system shall be checked and at least the following data shall be measured:
  - the percentage of arcing, and additionally the contact force,
  - the contact wire uplift at the support as the pantograph passes.

TM 3.2.1 OCS REQUIREMENTS - DIRECTIVE DRAWINGS - Dated October 2010

Directive Dwg. No.	Drawing Title
TM 3.2.1-A	Typical Open Route OCS Structure for Tangent Tracks – Speed Up to 125 mph
TM 3.2.1-B	Typical Open Route OCS Structure for Curved Tracks – Speed Up to 125 mph
TM 3.2.1-C	Typical OCS Support Structure Tangent Tracks on Viaduct – Speed Up to 125 mph
TM 3.2.1-D	Typical OCS Support Structure Curved Tracks on Viaduct -– Speed Up to 125 mph
TM 3.2.1-E	Typical Portal Structure OCS Arrangement Tangent Track with Turnout – Speed Up to 125 mph
TM 3.2.1-F	Typical Portal Structure OCS Arrangement on Three Curved Tracks– Speed Up to 125 mph
TM 3.2.1-G	Typical Portal Structure Support Arrangement - Multi-Tangent Track– Speed Up to 125 mph
TM 3.2.1-H	Typical OCS Support Structure for Four Tracks Intermediate Station - Speed up to 125 mph
TM 3.2.1-I	Typical OCS Equipment for New Circular Tunnel - Tangent Track - Speed up 125 mph
TM 3.2.1-J	Typical New Mined Tunnels OCS Arrangement Tangent Track - Speed up 125 mph
TM 3.2.1-K	Typical Cut and Cover Tunnel OCS Arrangement - Tangent Tracks – Speed Up to 125 mph
TM 3.2.1-L	Typical Cut and Cover Tunnel OCS Arrangement on Curved Tracks – Speed Up to 125 mph
TM 3.2.1-M	Typical OCS Headspan Arrangement Four Tracks Shared Use Corridor - Speed up to 125 mph
TM 3.2.1-N	Typical Open Trench OCS Arrangement on Tangent Tracks - Speed up to 125 mph
TM 3.2.1-O	Typical Open Trench OCS Arrangement on Curved Track - Speed up to 125 mph
TM 3.2.1-P	Typical Open Trench OCS Arrangement Wall Mounted Support on Tangent Track - Speed up to 125 mph
TM 3.2.1-Q	Typical Open Trench OCS Arrangement Wall Mounted Support on Curved Track - Speed up to 125 mph
TM 3.2.1-R	Typical Single Track Open Trench Arrangement OCS Wall Mounted Support on Tangent Track - Speed up to 125 mph
TM 3.2.1-S	Typical Single Track Open Trench Arrangement OCS Wall Mounted Support on Curved Track - Speed up to 125 mph
TM 3.2.1-T	Typical Open Trench OCS Arrangement Portal Structure on Tangent Track - Speed up to 125 mph

Directive Dwg. No.	Drawing Title
TM 3.2.1-U	Typical Catenary Free Running Chart for Overhead Bridge - Speed up to 125 mph
TM 3.2.1-AA	Typical OCS Support Structure for Two Tangent Tracks in Open Route - Speed Up to 220 mph
TM 3.2.1-AB	Typical OCS Support Structure for Two Curved Tracks in Open Route - Speed Up to 220 mph
TM 3.2.1-AC	Typical OCS Support Structure on Viaduct - Tangent Tracks - Speed Up to 220 mph
TM 3.2.1-AD	Typical OCS Support Structure on Viaduct - Curved Tracks - Speed Up to 220 mph
TM 3.2.1-AE	Typical Portal Structure OCS Arrangement Tangent Track with Turnout - Speed Up to 220 mph
TM 3.2.1-AF	Typical Portal Structure OCS Arrangement on Three Curved Tracks - Speed Up to 220 mph
TM 3.2.1-AG	Typical Portal Structure OCS Arrangement on Multiple Tangent Tracks - Speed Up to 220 mph
TM 3.2.1-AH	Typical OCS Support Structure for Four Tracks Immediate Station - Speed Up to 220 mph
TM 3.2.1-AI	Typical Circular Tunnels OSC Arrangement Tangent Track - Speed Up to 220 mph
TM 3.2.1-AJ	Typical OCS Equipment for Mined Tunnels - Tangent Track - Speed Up to 220 mph
TM 3.2.1-AK	Typical OCS Equipment for Cut and Cover Tunnels - Tangent Track - Speed Up to 220 mph
TM 3.2.1-AL	Typical Open Trench OCS Structure on Tangent Tracks - Speed Up to 220 mph
TM 3.2.1-AM	Typical Open Trench OCS Structure Curve Tracks - Speed Up to 220 mph
TM 3.2.1-AN	Typical Open Trench OCS Structure Wall Mounted Support Tangent Track - Speed Up to 220 mph
TM 3.2.1-AO	Typical Open Trench OCS Structure Wall Mounted Support Curved Track - Speed Up to 220 mph
TM 3.2.1-AP	Typical Single Track Open Trench Structure OCS Wall Mounted Support Tangent Track - Speed Up to 220 mph
TM 3.2.1-AQ	Typical Single Track Open Trench Structure on Wall Mounted Support on Curved Track - Speed Up to 220 mph
TM 3.2.1-AR	Typical Open Trench OCS Structure Portal Structure Tangent Tracks - 220 mph



TYPICAL OPEN ROUTE OCS STRUCTURE
FOR TANGENT TRACKS

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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
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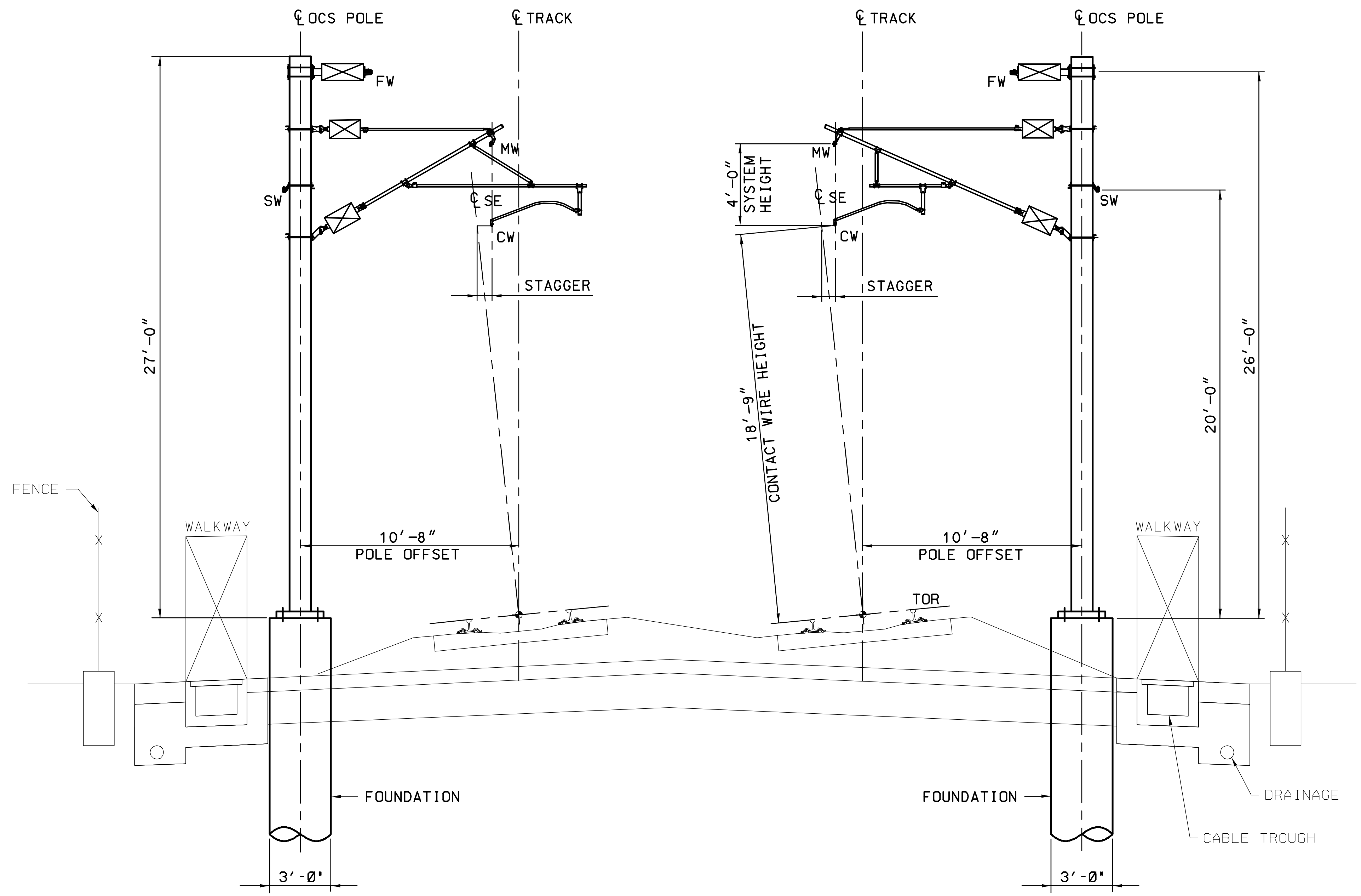
CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN ROUTE OCS STRUCTURE
FOR TANGENT TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-A
SCALE NTS
SHEET NO.



TYPICAL OPEN ROUTE OCS STRUCTURE
FOR CURVED TRACKS

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

NOTES:

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IN CHARGE K. JONG
DATE OCT. 2010

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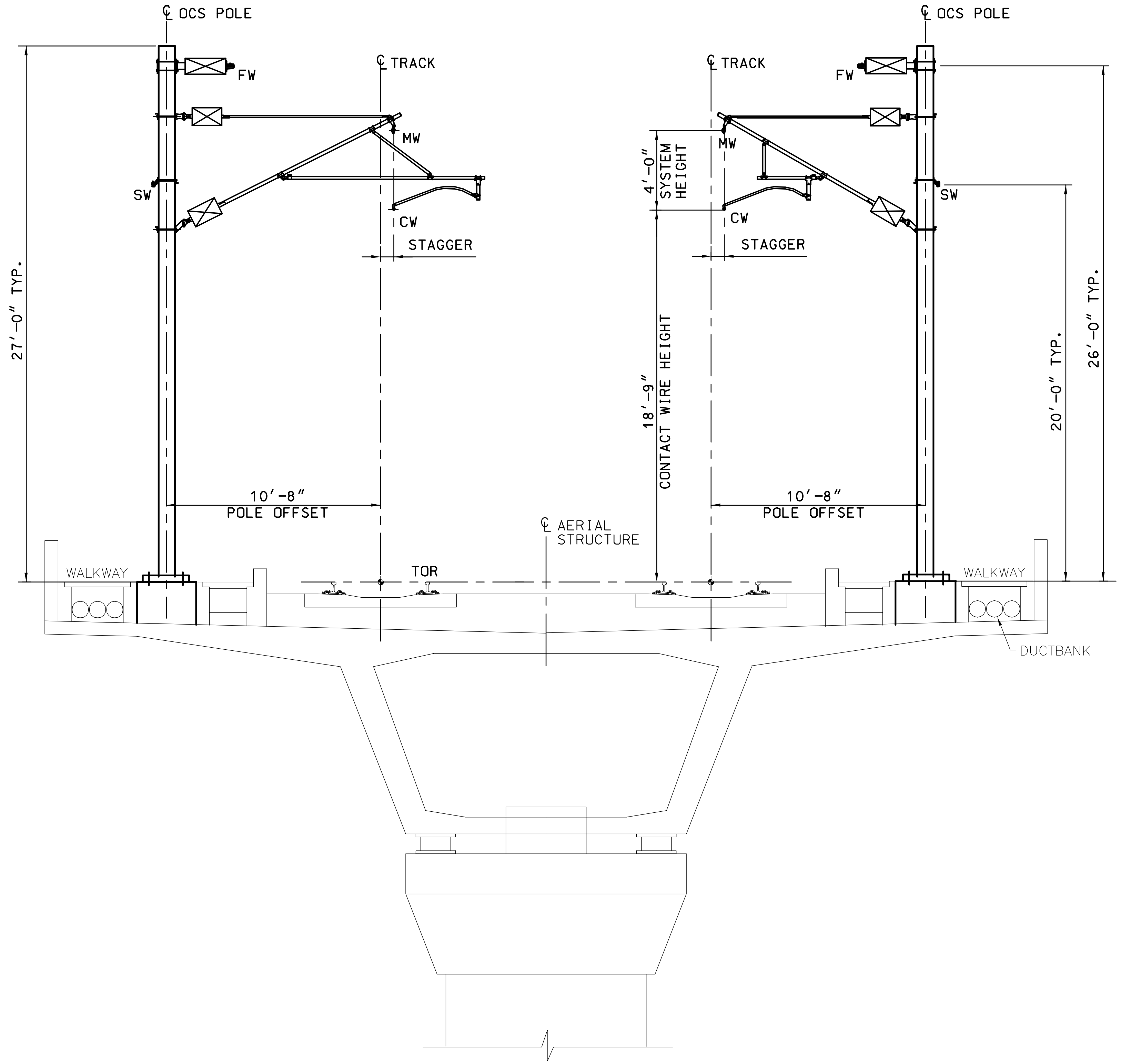
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN ROUTE OCS STRUCTURE
FOR CURVED TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-B
SCALE NTS
SHEET NO.



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

NOTES:

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2. FOR AERIAL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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REV	DATE	BY	CHK	APP	DESCRIPTION

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CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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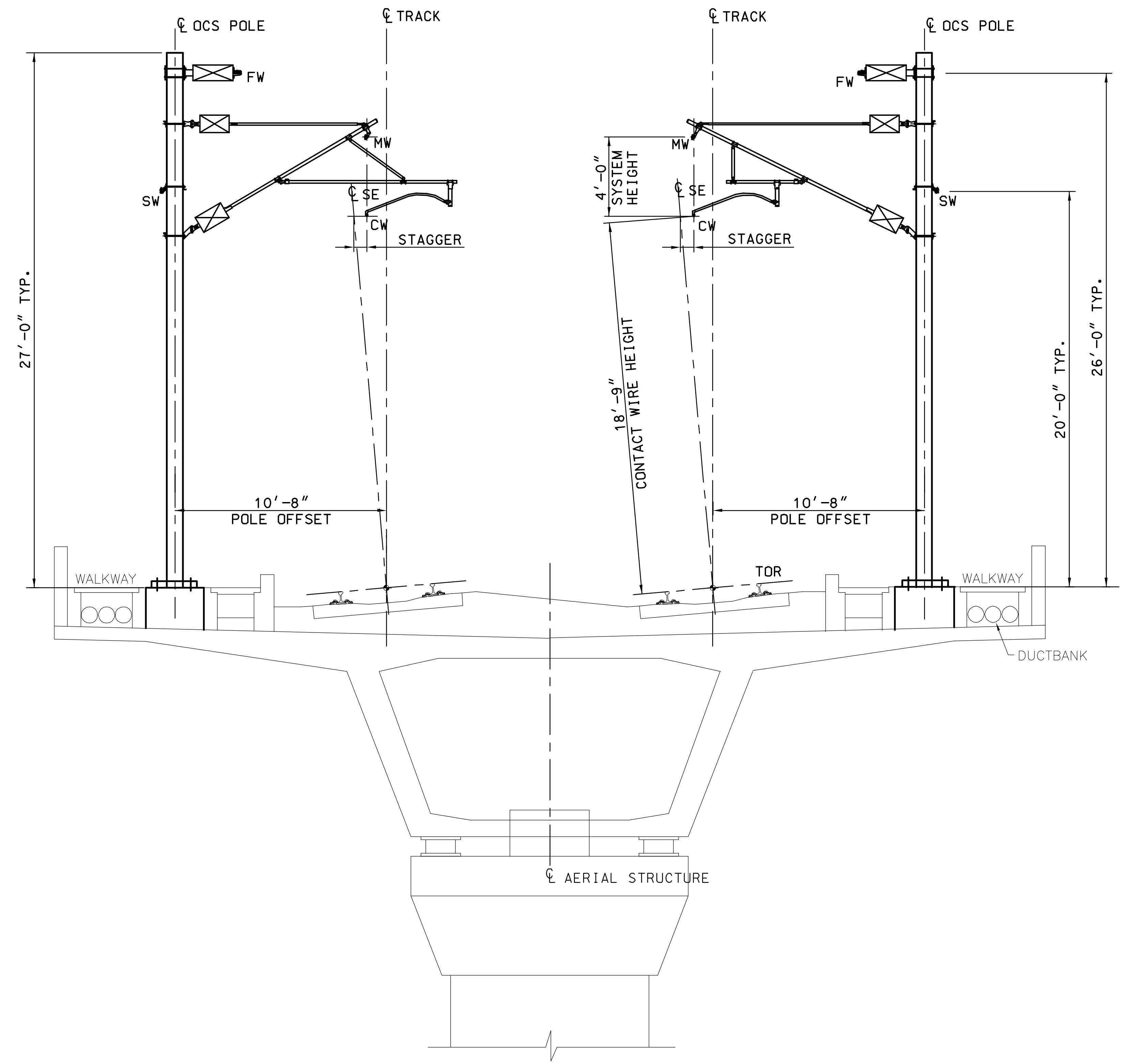
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS SUPPORT STRUCTURE
TANGENT TRACKS ON VIADUCT
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-C
SCALE NTS
SHEET NO.



TYPICAL OCS SUPPORT STRUCTURE
CURVED 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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.

2. FOR AERIAL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

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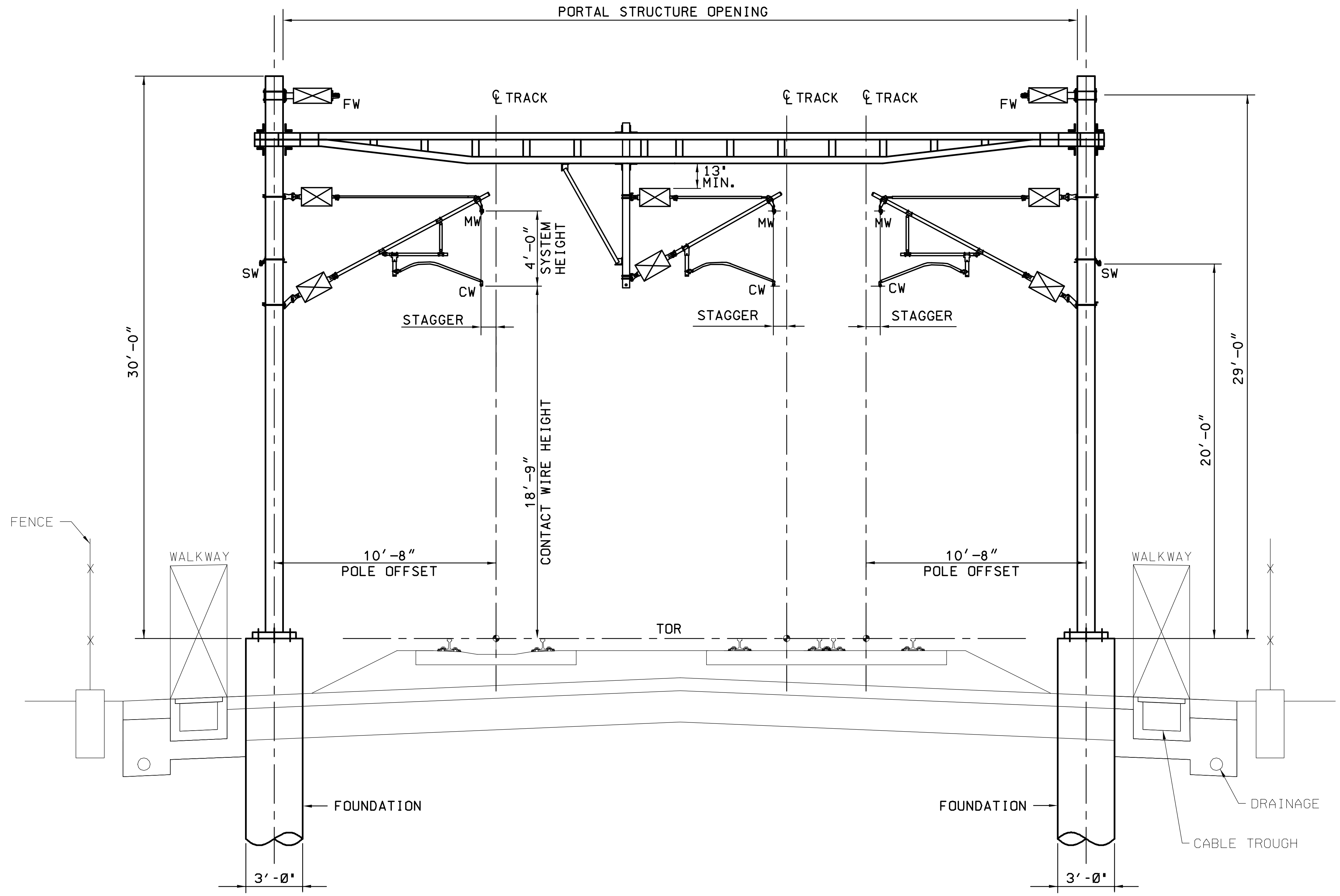
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS SUPPORT STRUCTURE
CURVED TRACKS ON VIADUCT
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-D
SCALE NTS
SHEET NO.



TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
TANGENT TRACK WITH TURNOUT

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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

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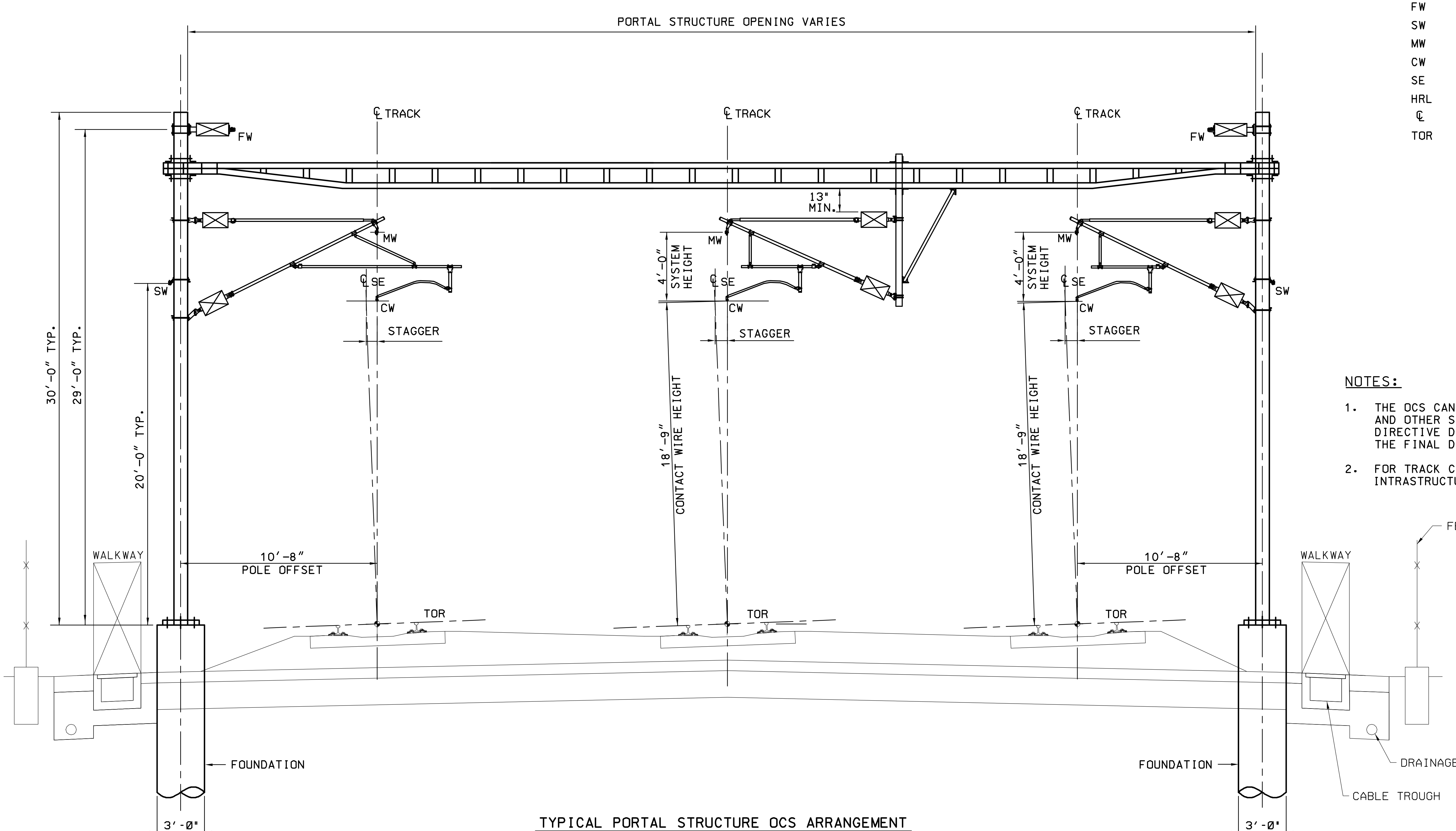
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
TANGENT TRACKS WITH TURNOUT
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-E
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
℄	CENTERLINE
TOR	TOP OF RAIL



NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INTRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
ON THREE CURVED TRACKS

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

REV	DATE	BY	CHK	APP	DESCRIPTION

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IN CHARGE K. JONG
DATE OCT. 2010

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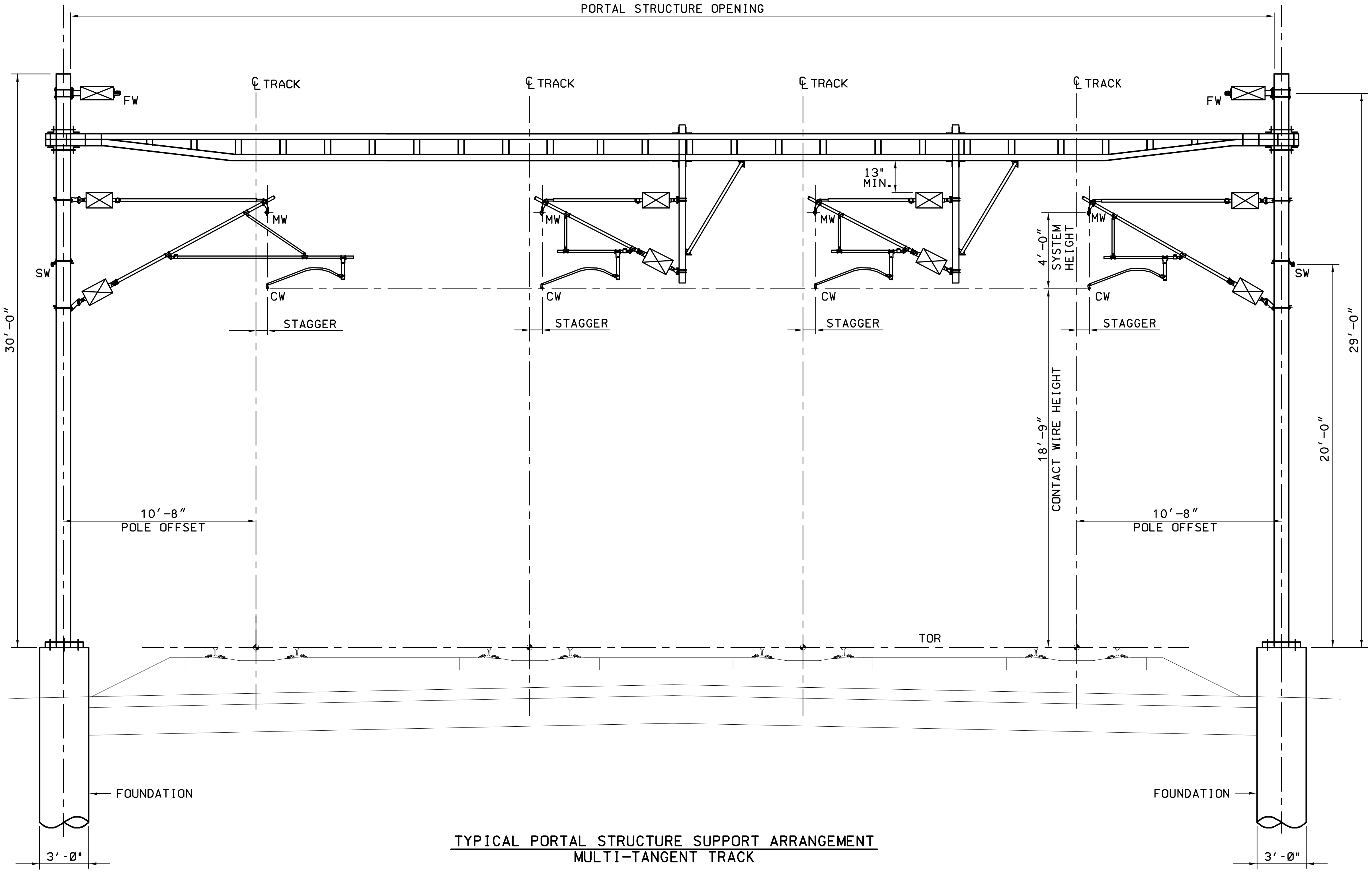
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
ON THREE CURVED TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-F
SCALE NTS
SHEET NO.



TYPICAL PORTAL STRUCTURE SUPPORT ARRANGEMENT
MULTI-TANGENT TRACK

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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
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DATE OCT. 2010

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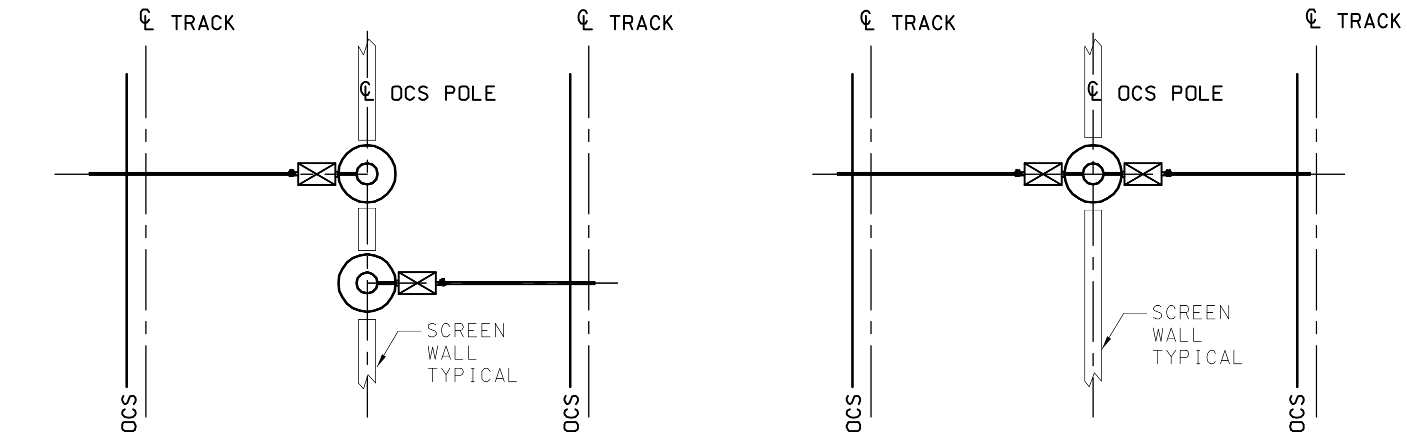
CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL PORTAL STRUCTURE SUPPORT ARRANGEMENT
MULTI-TANGENT TRACK
SPEED UP TO 125 MPH

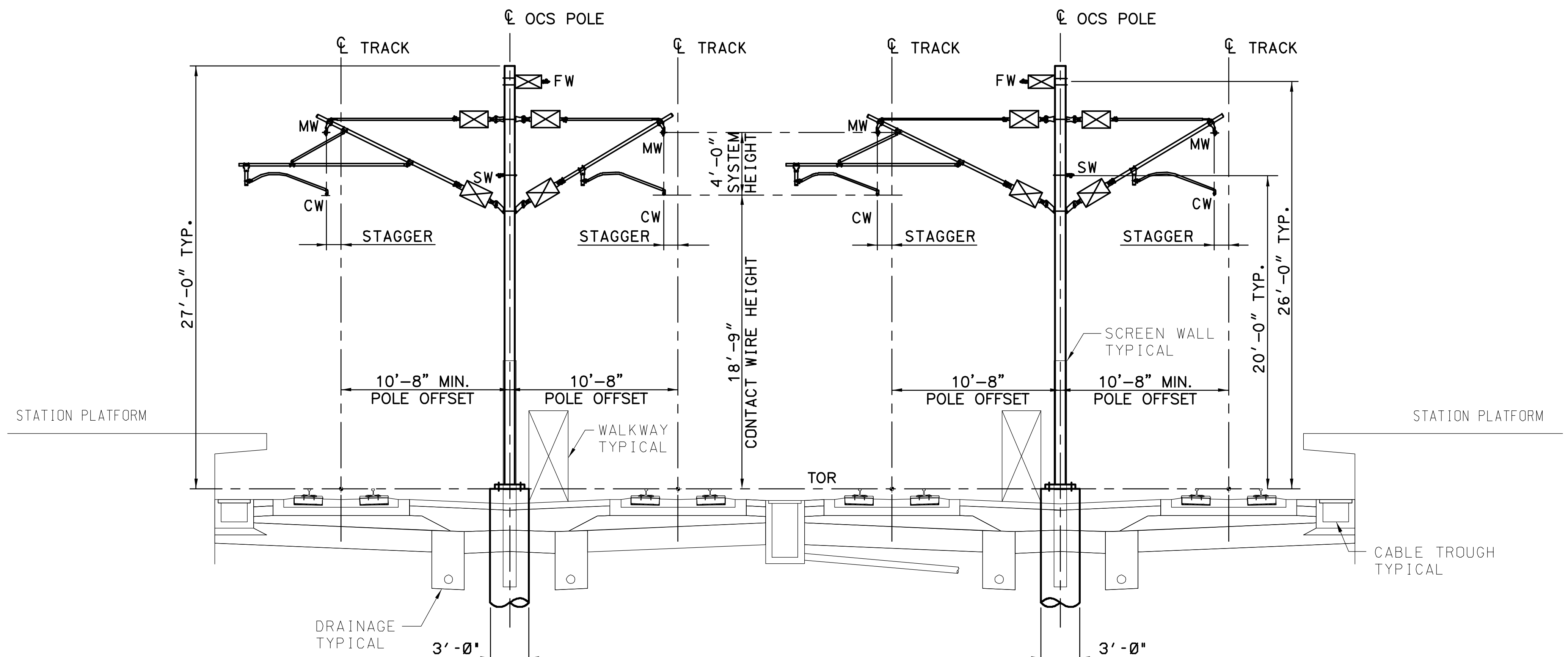
CONTRACT NO.
DRAWING NO. TM 3.2.1-G
SCALE NTS
SHEET NO.



ALTERNATIVE 1
SEE NOTE

ALTERNATIVE 2
SEE NOTE

OCS PLAN VIEW



TYPICAL OCS SUPPORT ARRANGEMENT
4-TRACK INTERMEDIATE STATION
OUTSIDE BOARDING PASSENGER PLATFORMS

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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. THE OCS SUPPORT ARRANGEMENT USING SINGLE CANTILEVERS ON SEPARATE CENTER POLES OR BACK-TO BACK CANTILEVERS ON A COMMON CENTER POLE SHALL BE CONFIRMED BY THE FINAL SYSTEM DESIGNER BASED ON OCS DYNAMIC SIMULATIONS.
3. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

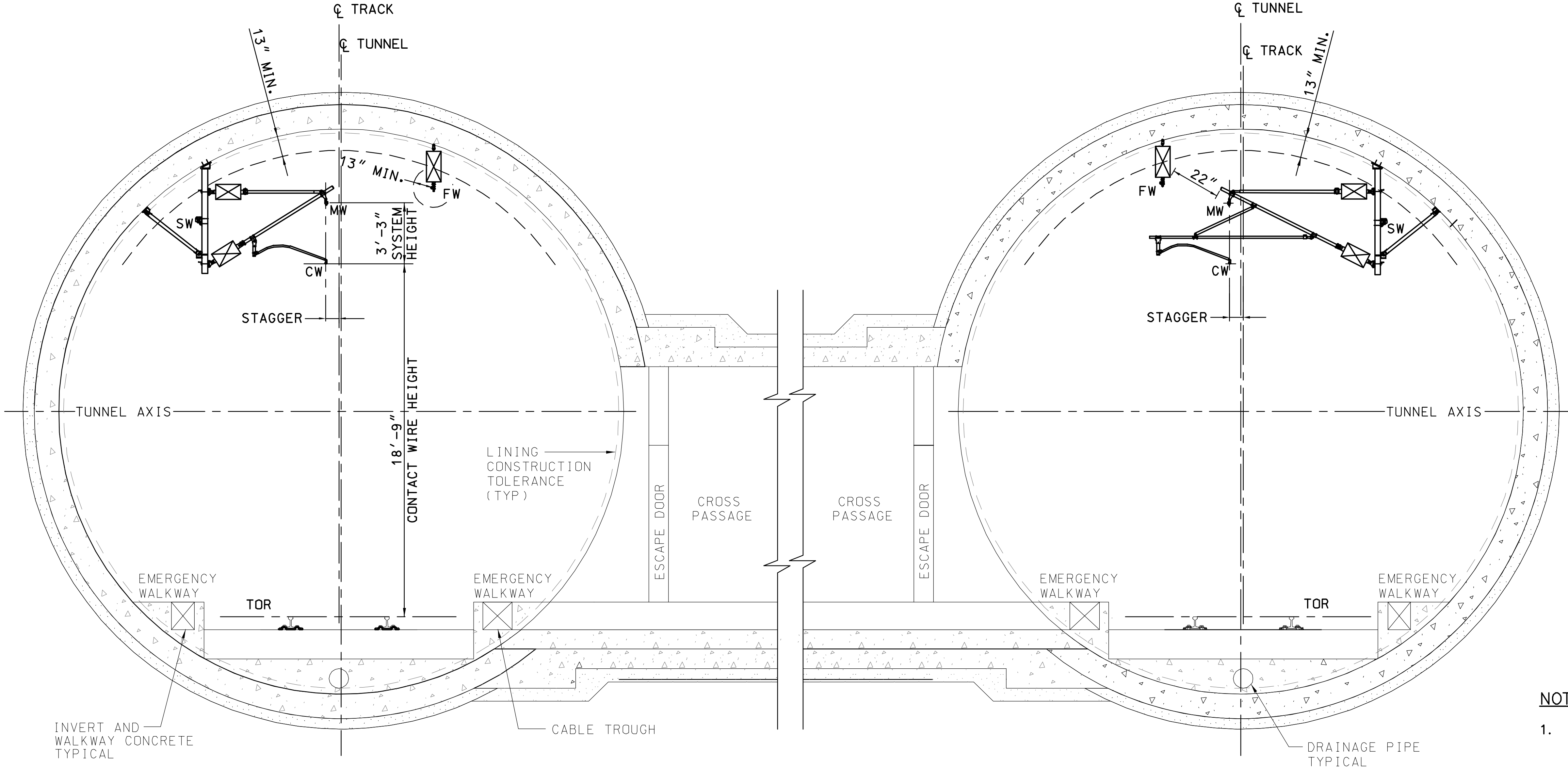
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLYCALIFORNIA *Without ever leaving the ground.*

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS SUPPORT STRUCTURE
FOR FOUR TRACKS INTERMEDIATE STATION
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-H
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
℄	CENTERLINE
TOR	TOP OF RAIL



TYPICAL NEW CIRCULAR TUNNEL OCS ARRANGEMENT
TANGENT TRACK

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25 KV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY LIVE 25 KV PARTS.
4. FOR CIRCULAR TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

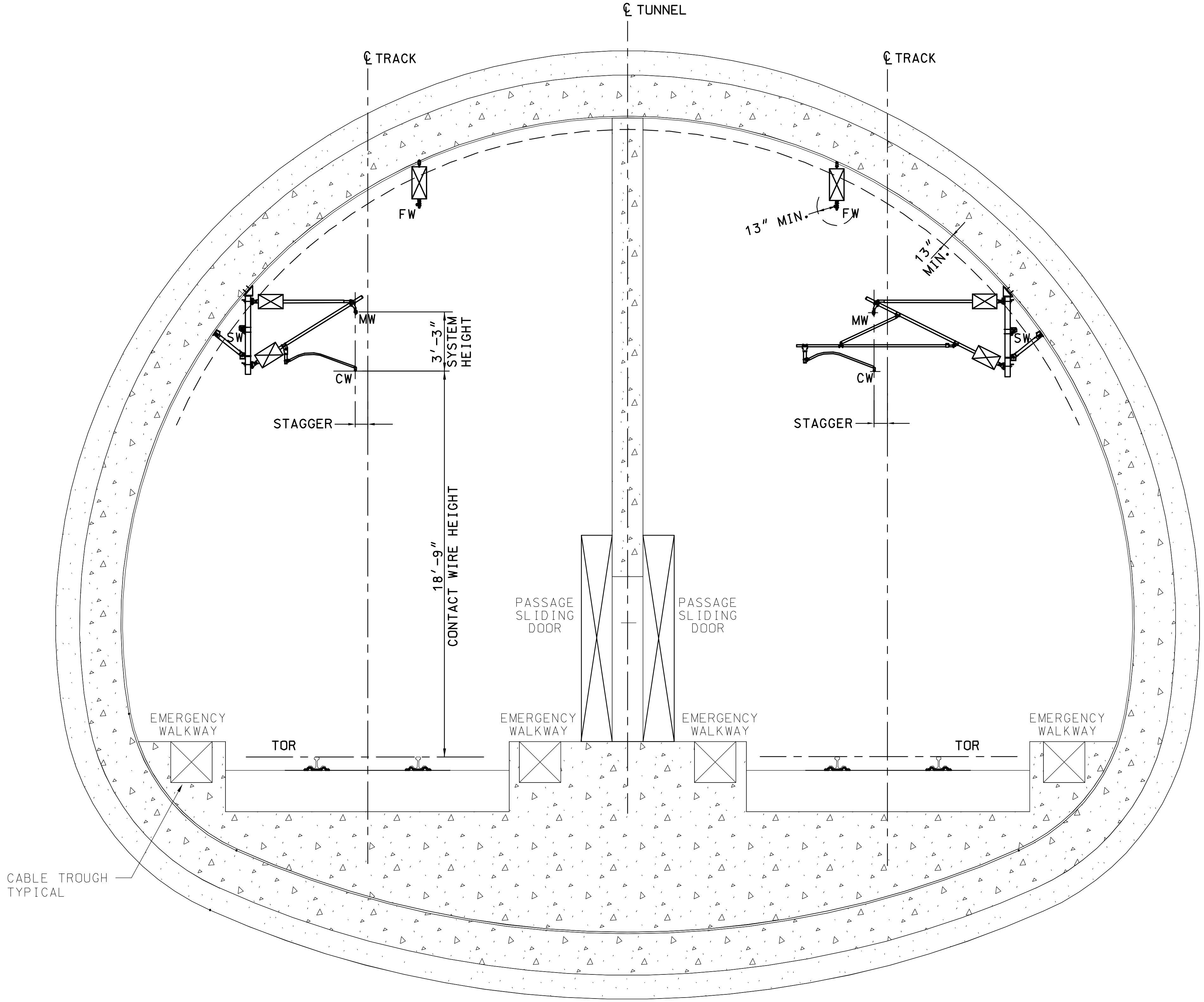
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

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

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS EQUIPMENT FOR
NEW CIRCULAR TUNNEL - TANGENT TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-I
SCALE NTS
SHEET NO.



TYPICAL NEW MINED TUNNEL OCS ARRANGEMENT
TANGENT TRACK

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

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25 KV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY LIVE 25 KV PARTS.
4. FOR MINED TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

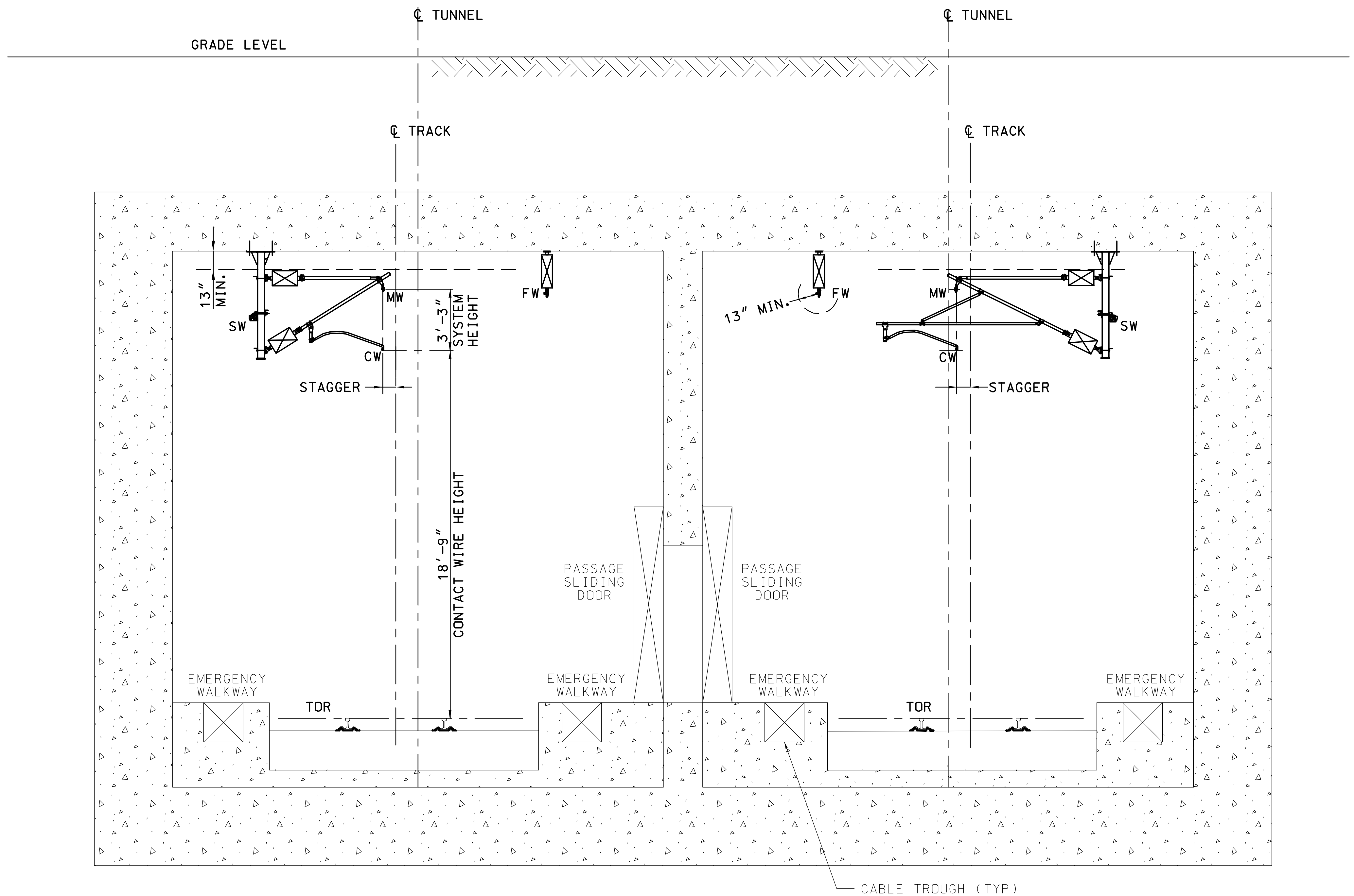
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

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

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL NEW MINED TUNNEL OCS ARRANGEMENT
TANGENT TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-J
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
℄	CENTERLINE
TOR	TOP OF RAIL

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25 KV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY LIVE 25 KV PARTS.
4. FOR CUT AND COVER TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL CUT AND COVER TUNNEL OCS ARRANGEMENT
TANGENT TRACKS

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

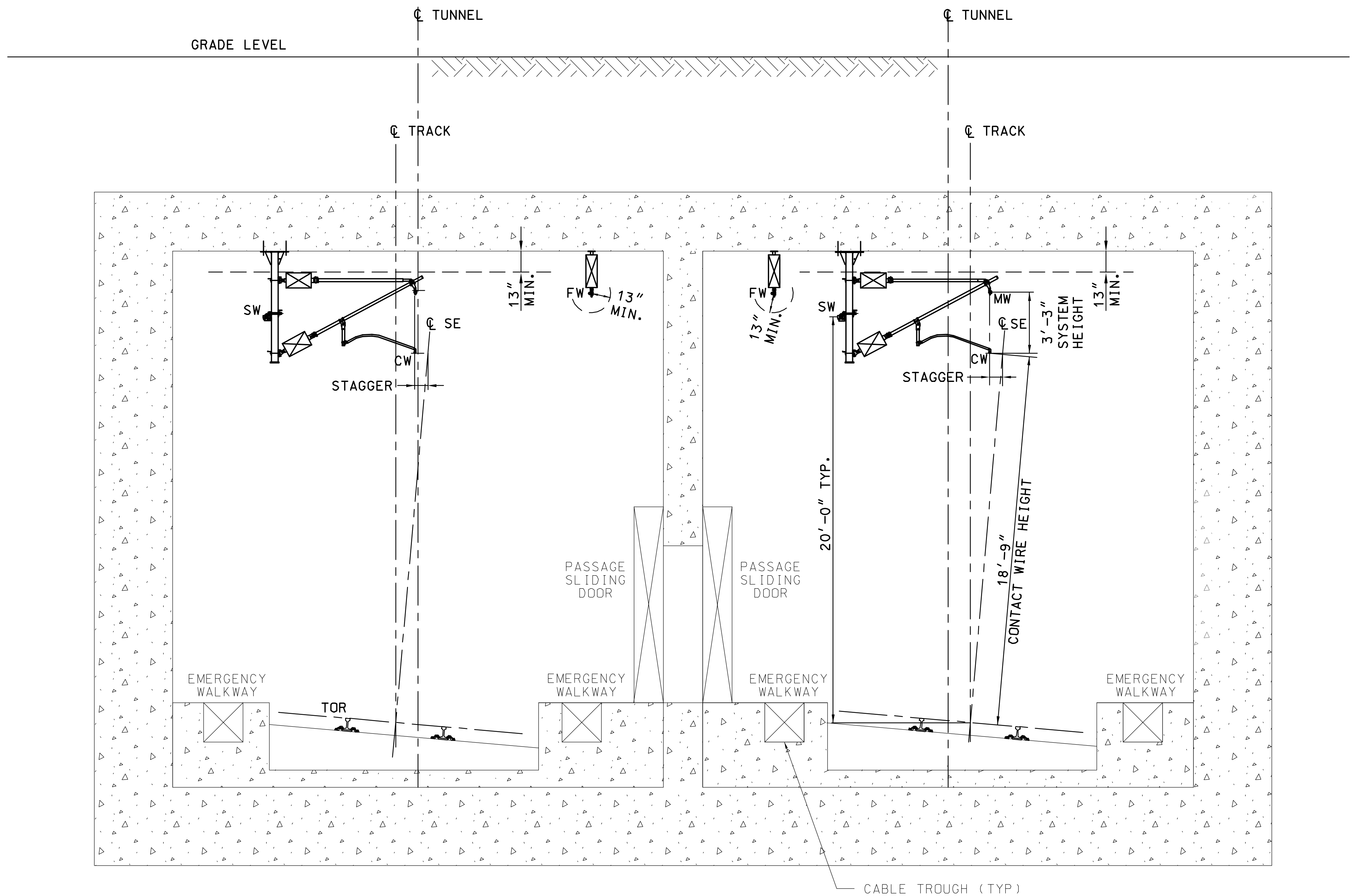
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL CUT AND COVER TUNNEL OCS ARRANGEMENT
TANGENT TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-K
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
℄	CENTERLINE
TOR	TOP OF RAIL



TYPICAL CUT AND COVER TUNNEL OCS ARRANGEMENT
ON CURVED TRACKS

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25 KV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY LIVE 25 KV PARTS.
4. FOR CUT AND COVER TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

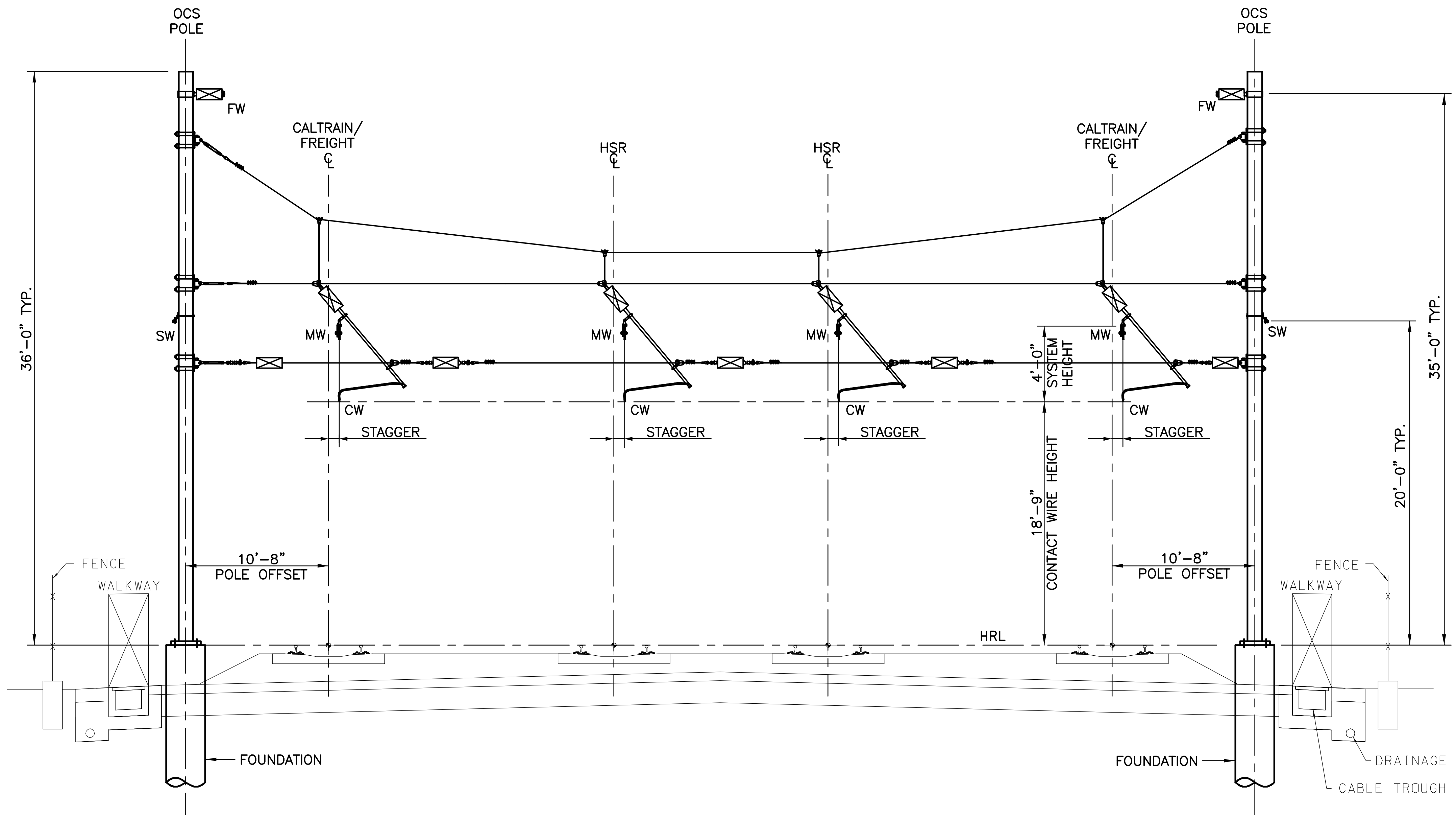
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL CUT AND COVER TUNNEL OCS ARRANGEMENT
ON CURVED TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-L
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
℄	CENTERLINE
TOR	TOP OF RAIL



NOTES:

1. THE HEADSPAN CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEM IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTURCTURE DIRECTIVE DRAWINGS.

TYPICAL OCS HEADSPAN ARRANGEMENT – FOUR TANGENT TRACKS
SHARED USE CORRIDOR AND SPEED UP TO 125 MPH
FOR CALTRAIN CORRIDOR ONLY

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

REV	DATE	BY	CHK	APP	DESCRIPTION

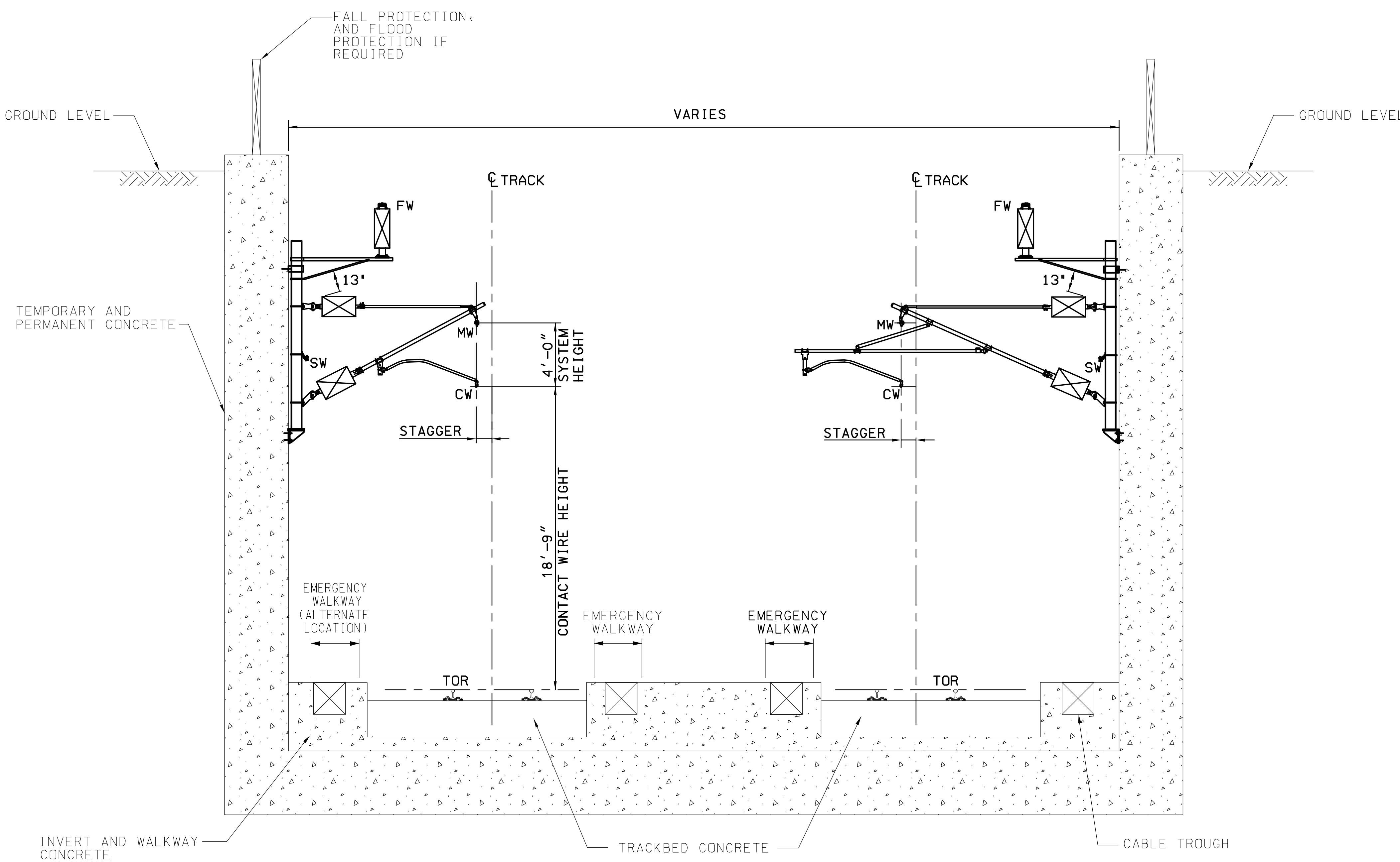
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

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

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS HEADSPAN ARRANGEMENT
FOUR TANGENT TRACKS SHARED USE CORRIDOR
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-M
SCALE NTS
SHEET NO.



TYPICAL OPEN TRENCH OCS ARRANGEMENT
ON TANGENT TRACKS

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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

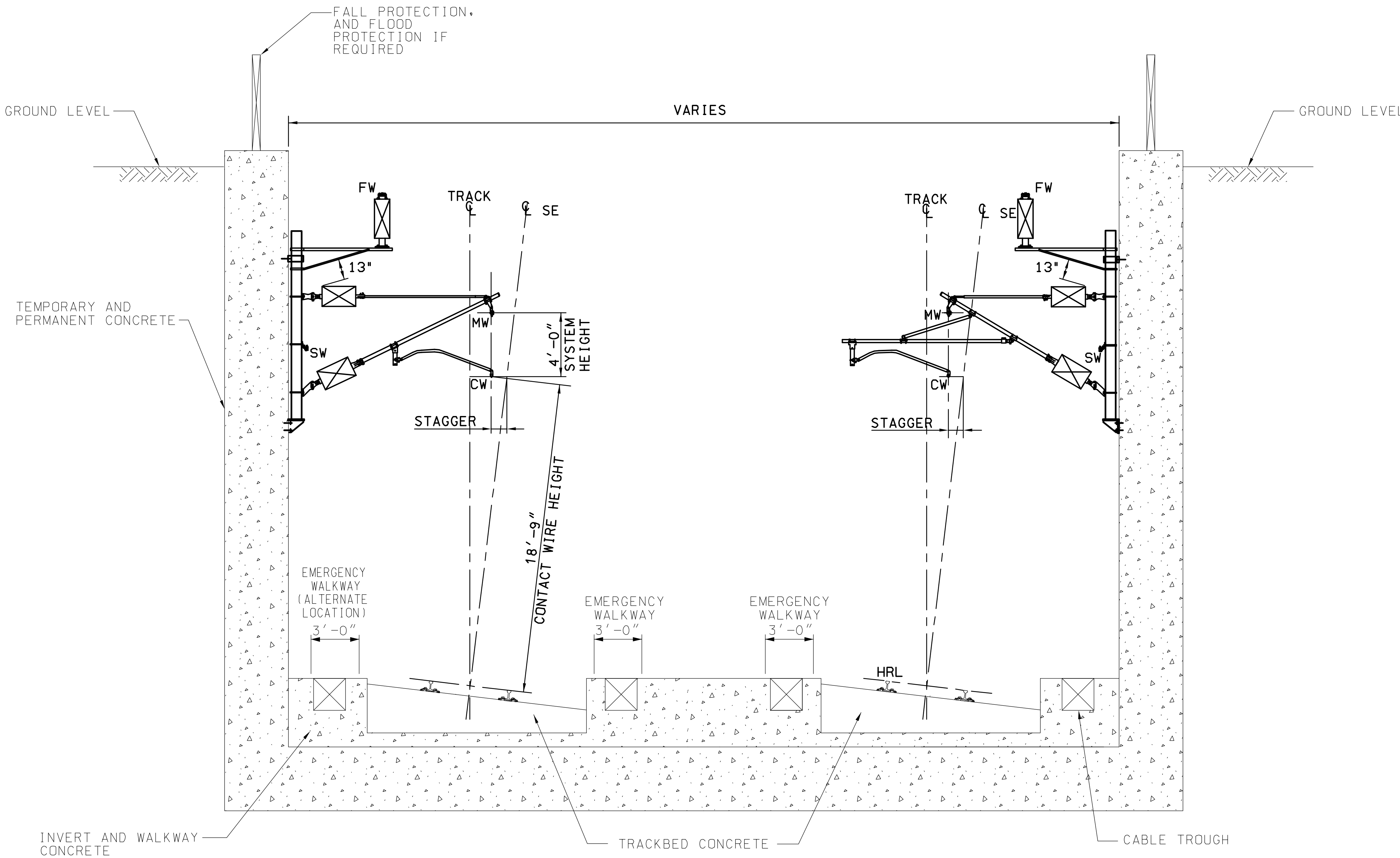
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS ARRANGEMENT
ON TANGENT TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-N
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
℄	CENTERLINE
TOR	TOP OF RAIL



TYPICAL OPEN TRENCH OCS SUPPORT ARRANGEMENT
ON CURVED TRACKS

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

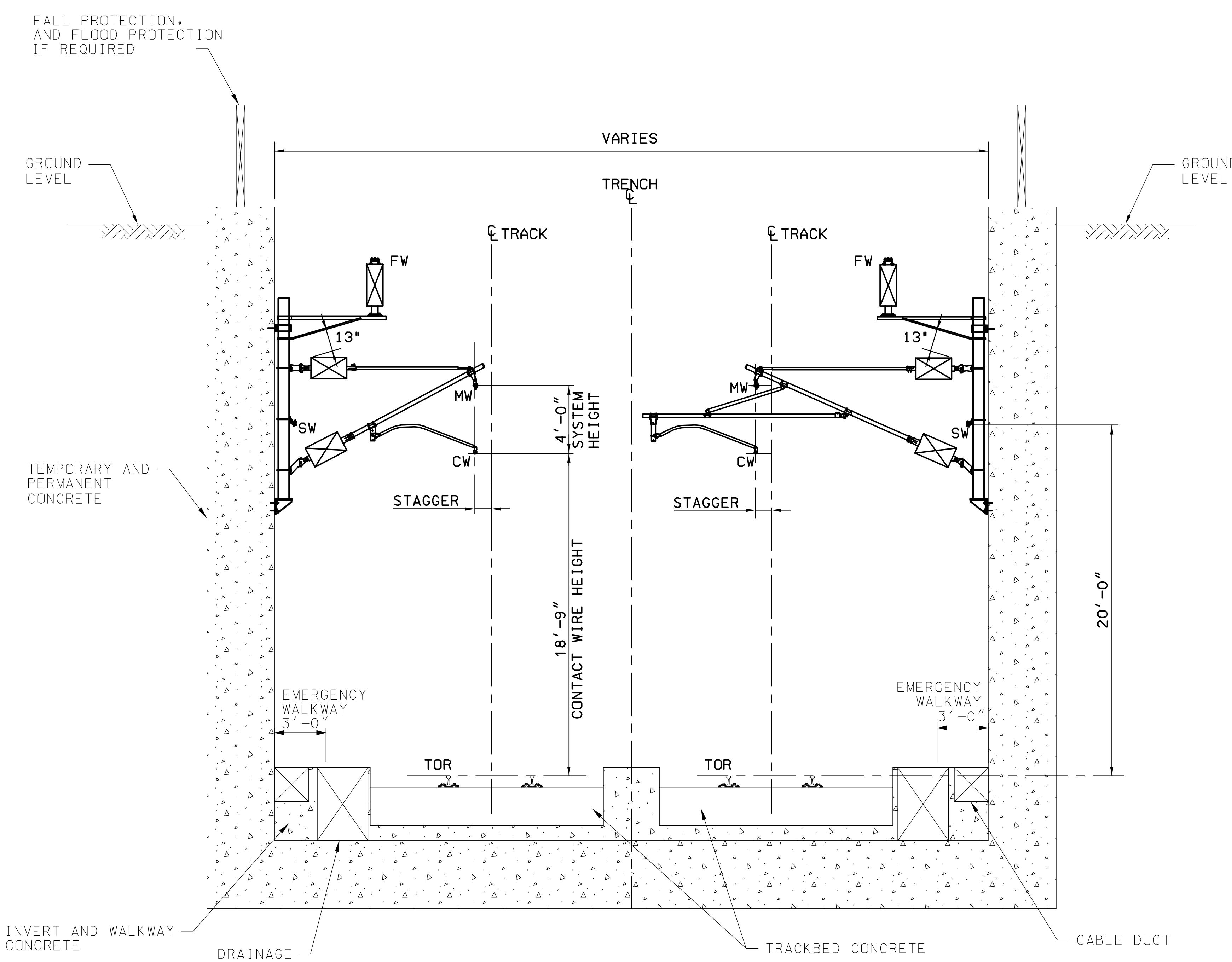
PB PARSONS BRINCKERHOFF

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

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS ARRANGEMENT
ON CURVED TRACKS
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-O
SCALE NTS
SHEET NO.

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



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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL OPEN TRENCH OCS SUPPORT ARRANGEMENT
WALL MOUNTED SUPPORT ON TANGENT TRACK

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

REV	DATE	BY	CHK	APP	DESCRIPTION

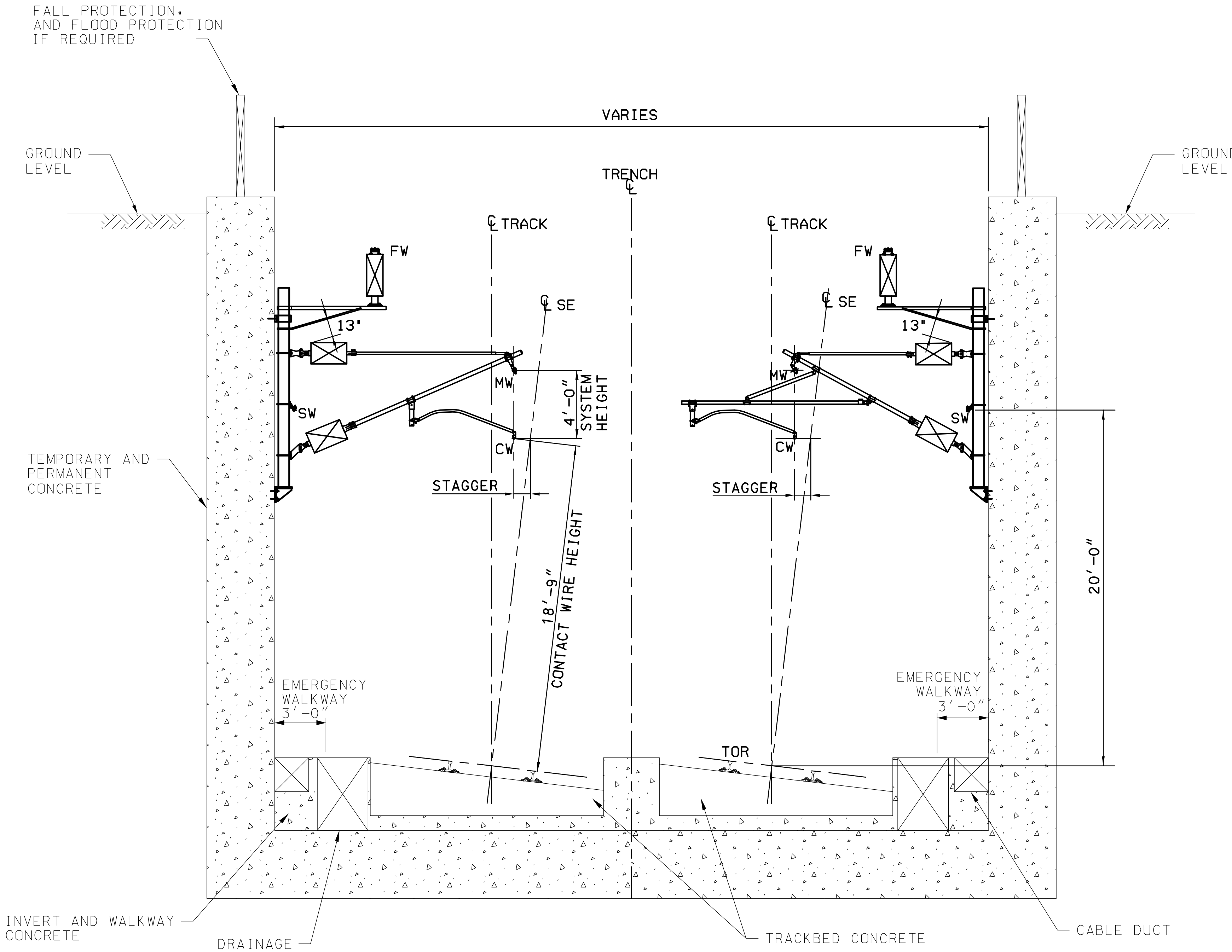
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 OPEN TRENCH OCS ARRANGEMENT
WALL MOUNTED SUPPORT ON TANGENT TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-P
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
℄	CENTERLINE
TOR	TOP OF RAIL

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL OPEN TRENCH OCS SUPPORT ARRANGEMENT
WALL MOUNTED SUPPORT ON CURVED TRACK

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

REV	DATE	BY	CHK	APP	DESCRIPTION

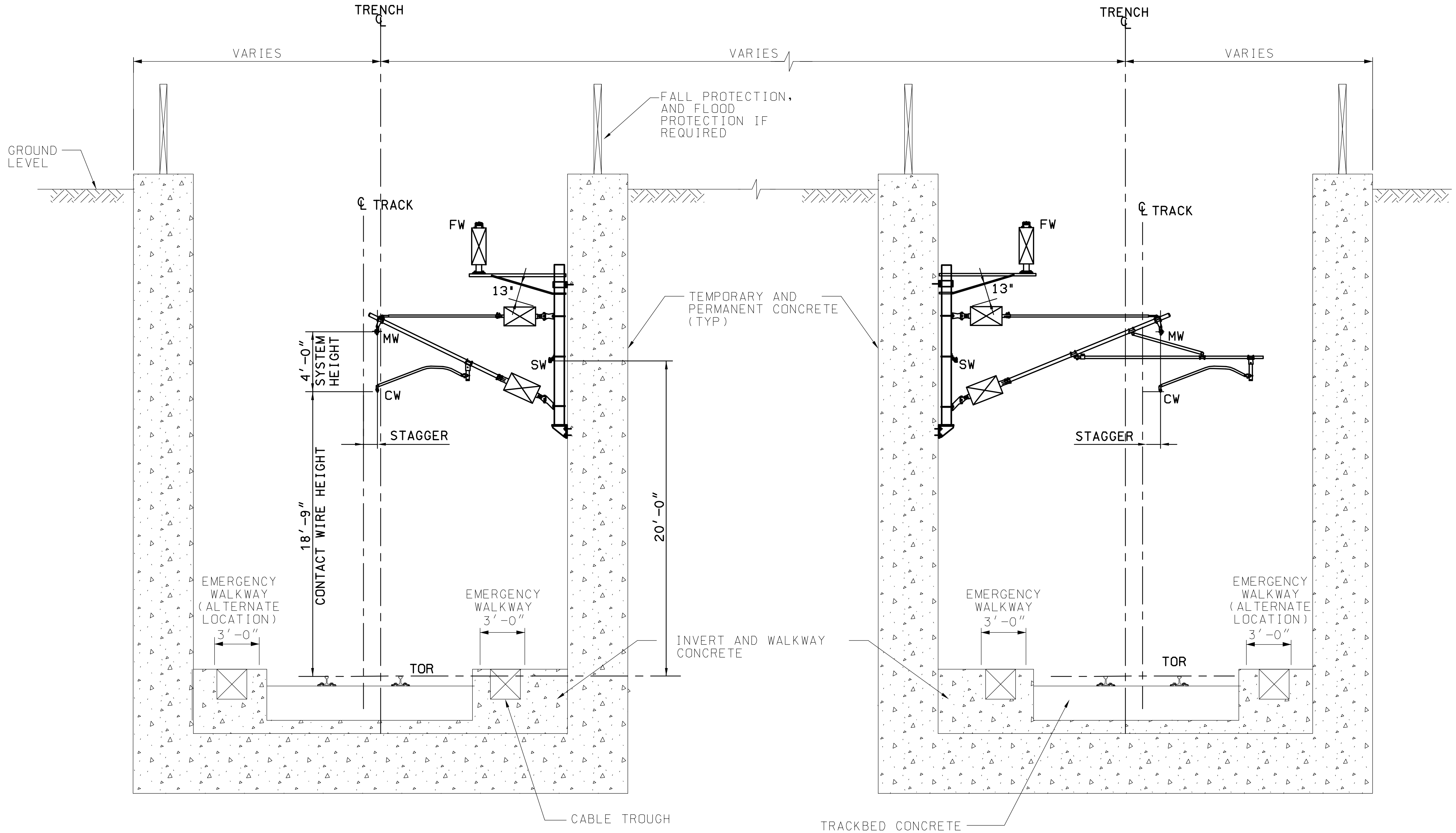
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 OPEN TRENCH OCS ARRANGEMENT
WALL MOUNTED SUPPORT ON CURVED TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-Q
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
℄	CENTERLINE
TOR	TOP OF RAIL

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL SINGLE TRACK OPEN TRENCH ARRANGEMENT
OCS WALL MOUNTED SUPPORT ON TANGENT TRACK

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

REV	DATE	BY	CHK	APP	DESCRIPTION

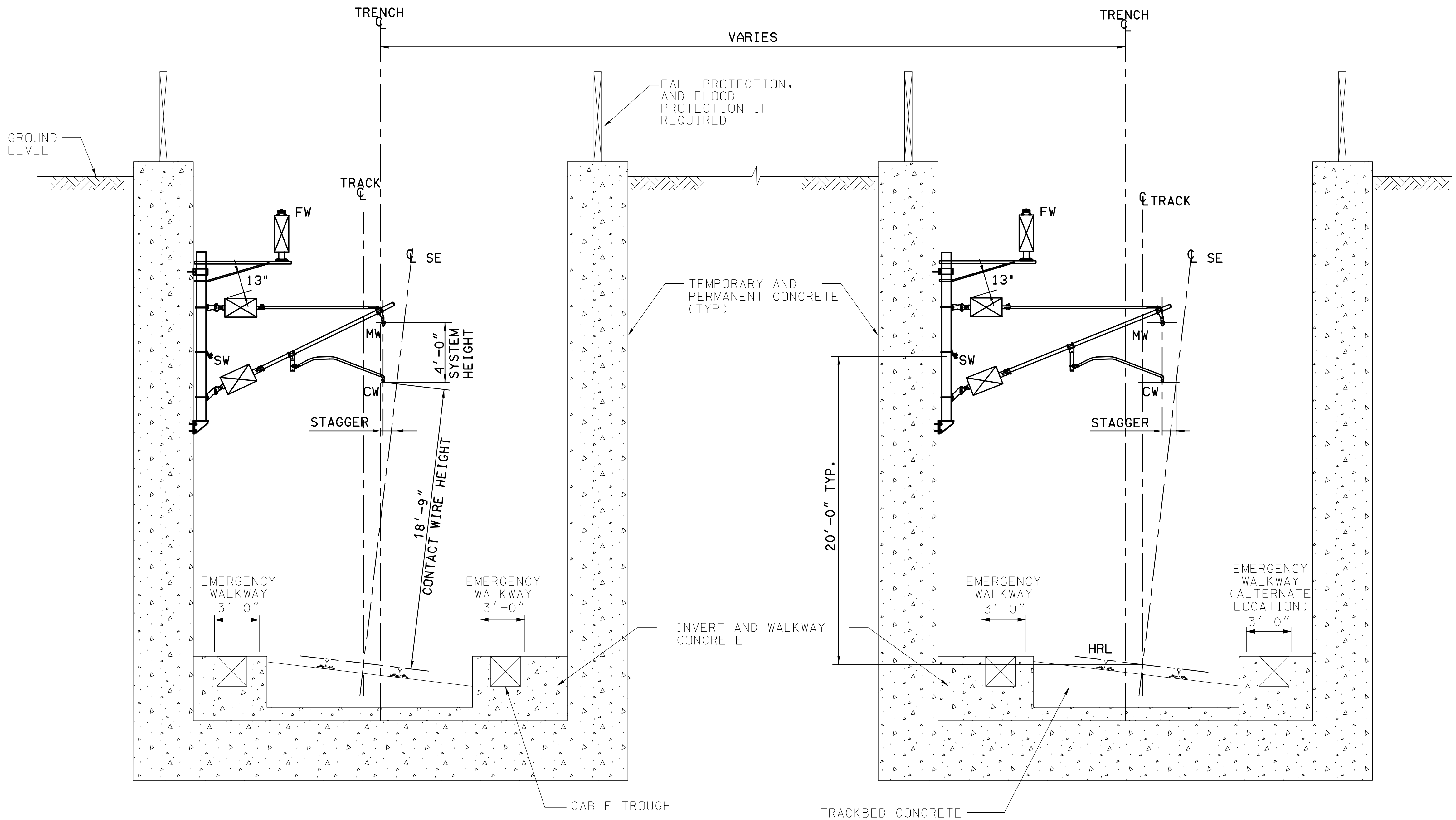
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 SINGLE TRACK OPEN TRENCH ARRANGEMENT
OCS WALL MOUNTED SUPPORT ON TANGENT TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-R
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
℄	CENTERLINE
TOR	TOP OF RARIL

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL SINGLE TRACK OPEN TRENCH ARRANGEMENT
OCS WALL MOUNTED SUPPORT ON CURVED TRACK

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

REV	DATE	BY	CHK	APP	DESCRIPTION

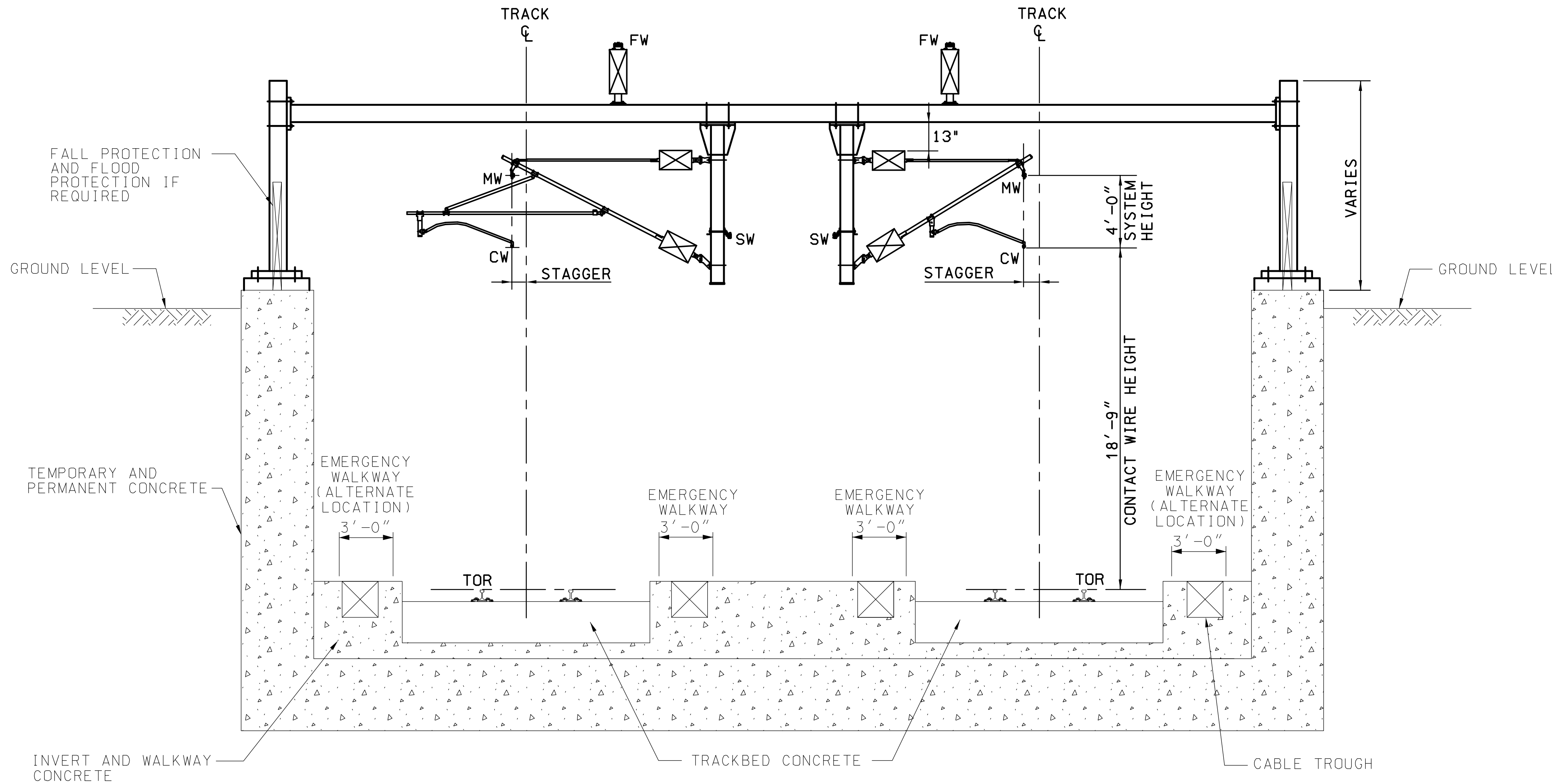
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 SINGLE TRACK OPEN TRENCH ARRANGEMENT
OCS WALL MOUNTED SUPPORT ON CURVED TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-S
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
℄	CENTERLINE
TOR	TOP OF RAIL

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL OPEN TRENCH OCS ARRANGEMENT
PORTAL STRUCTURE SUPPORT ON TANGENT TRACK

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

REV	DATE	BY	CHK	APP	DESCRIPTION

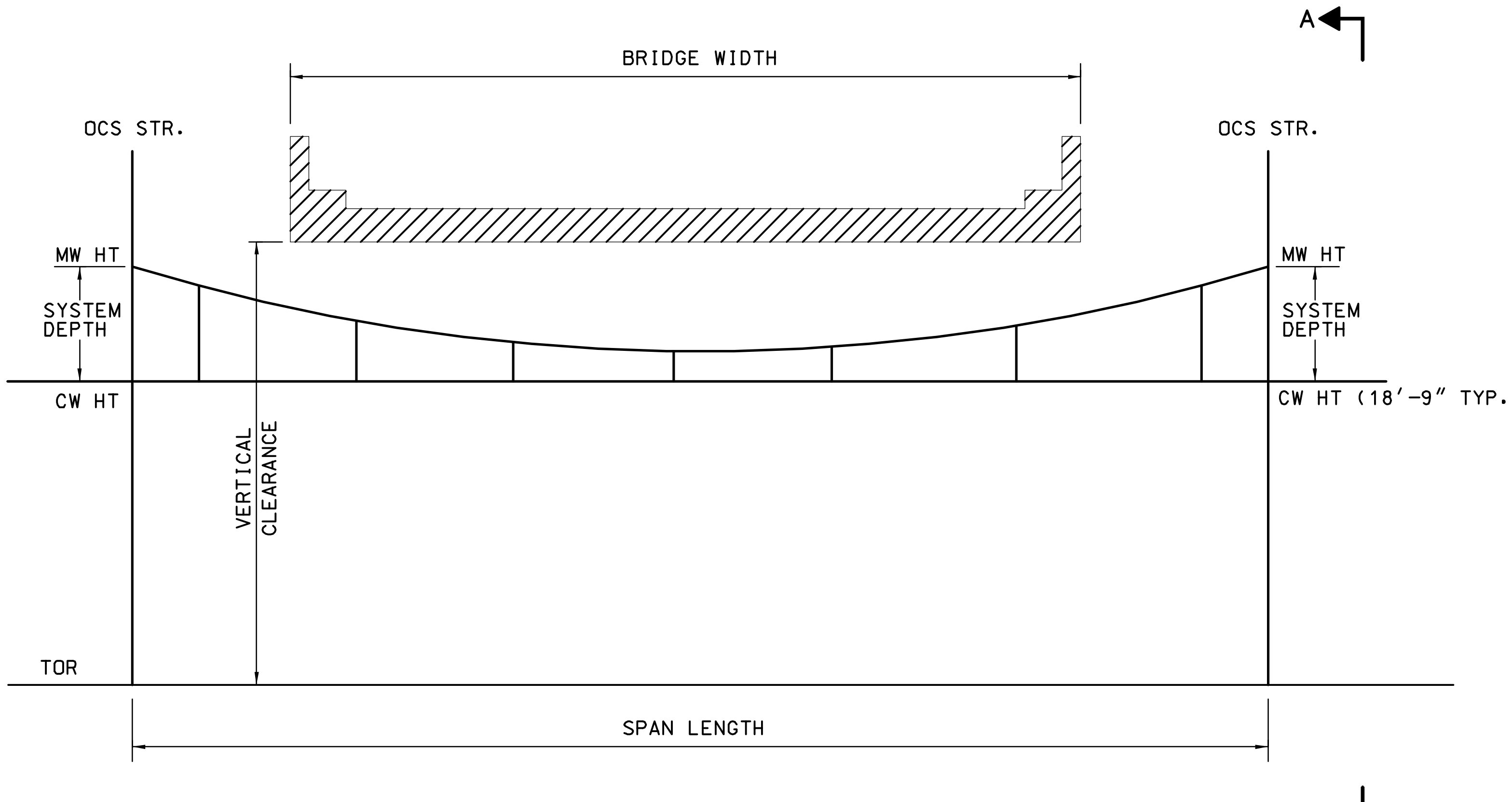
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

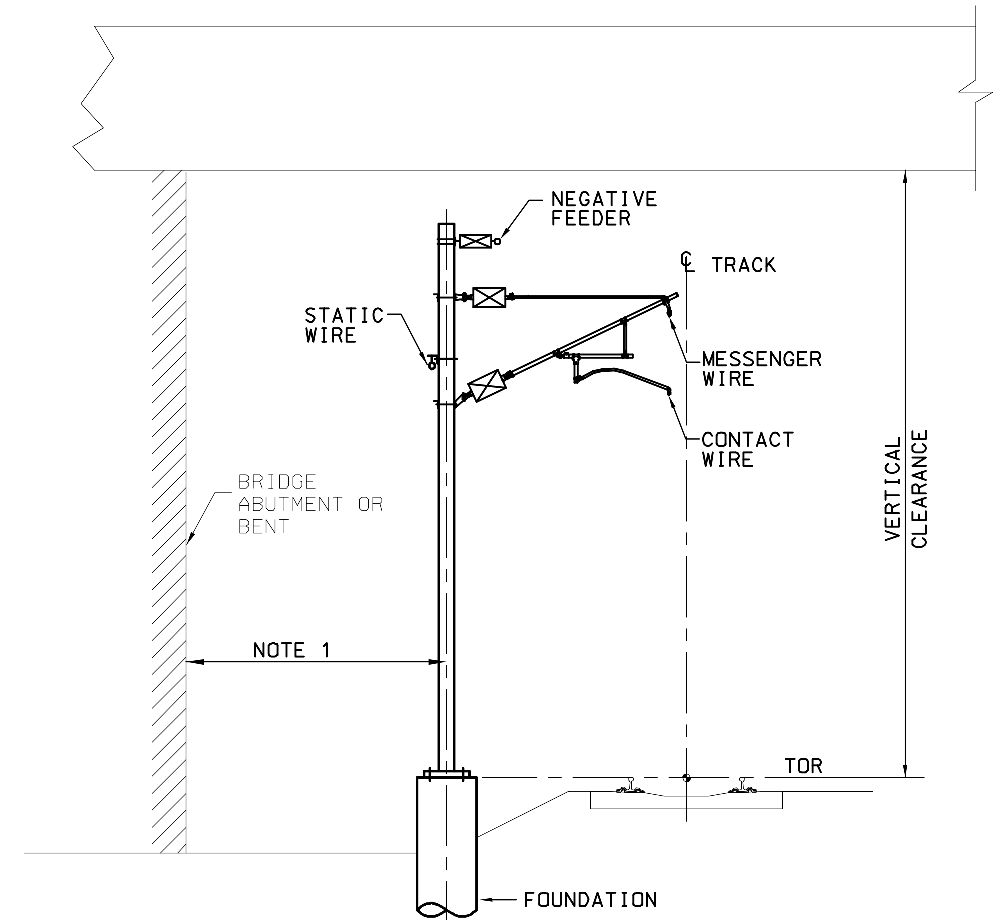
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA *Without ever leaving the ground.*

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS ARRANGEMENT
PORTAL STRUCTURE ON TANGENT TRACK
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-T
SCALE NTS
SHEET NO.



CATENARY PROFILE



VIEW A–A

MINIMUM VERTICAL CLEARANCE FOR SPEED UP TO 125 MPH					
CONDITIONS	NO BRIDGE ATTACHMENT				BRIDGE ATTACHMENT ALLOWED
	NEW BRIDGE	EXISTING BRIDGE	EXISTING BRIDGE	EXISTING BRIDGE	EXISTING BRIDGE
MAXIMUM BRIDGE WIDTH	200'	200'	120'	50'	-
OCS SPAN LENGTH	210'	210'	210'	210'	60'
OCS FREE RUNNING WITH FULL SYSTEM DEPTH (4'-0") VERTICAL HEIGHT REQ'D	27'-0"	24'-0"	23'-0"	22'-6"	-
OCS FREE RUNNING WITH REDUCED SYSTEM DEPTH (3'-0") VERTICAL HEIGHT REQ'D	-	23'-0"	22'-0"	21'-6"	-
OCS FREE RUNNING WITH REDUCED SYSTEM DEPTH (1'-0") VERTICAL HEIGHT REQ'D	-	-	-	-	21'-6"

NOTES:

1. WHEN THE VERTICAL CLEARANCE IS LESS THAN 27', NEGATIVE FEEDER CABLE SHALL BE INSTALLED ON THE FIELD SIDE OF THE POLE. IN THAT CASE, THE MINIMUM CLEARANCE 7'-6" FROM THE CENTER OF THE POLE TO THE BRIDGE ABUTMENT OR BENT SHALL BE MAINTAINED.

2. THESE CLEARANCES ARE BASED ON CuMg05 AC-150 CONTACT WIRE WITH 4,500LB TENSION AND 300 KCMIL MESSENGER WIRE WITH 5,000LB TENSION. THE VERTICAL CLEARANCE MIGHT BE ADJUSTED BASED ON THE FINAL WIRE TENSIONS AND MATERIALS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

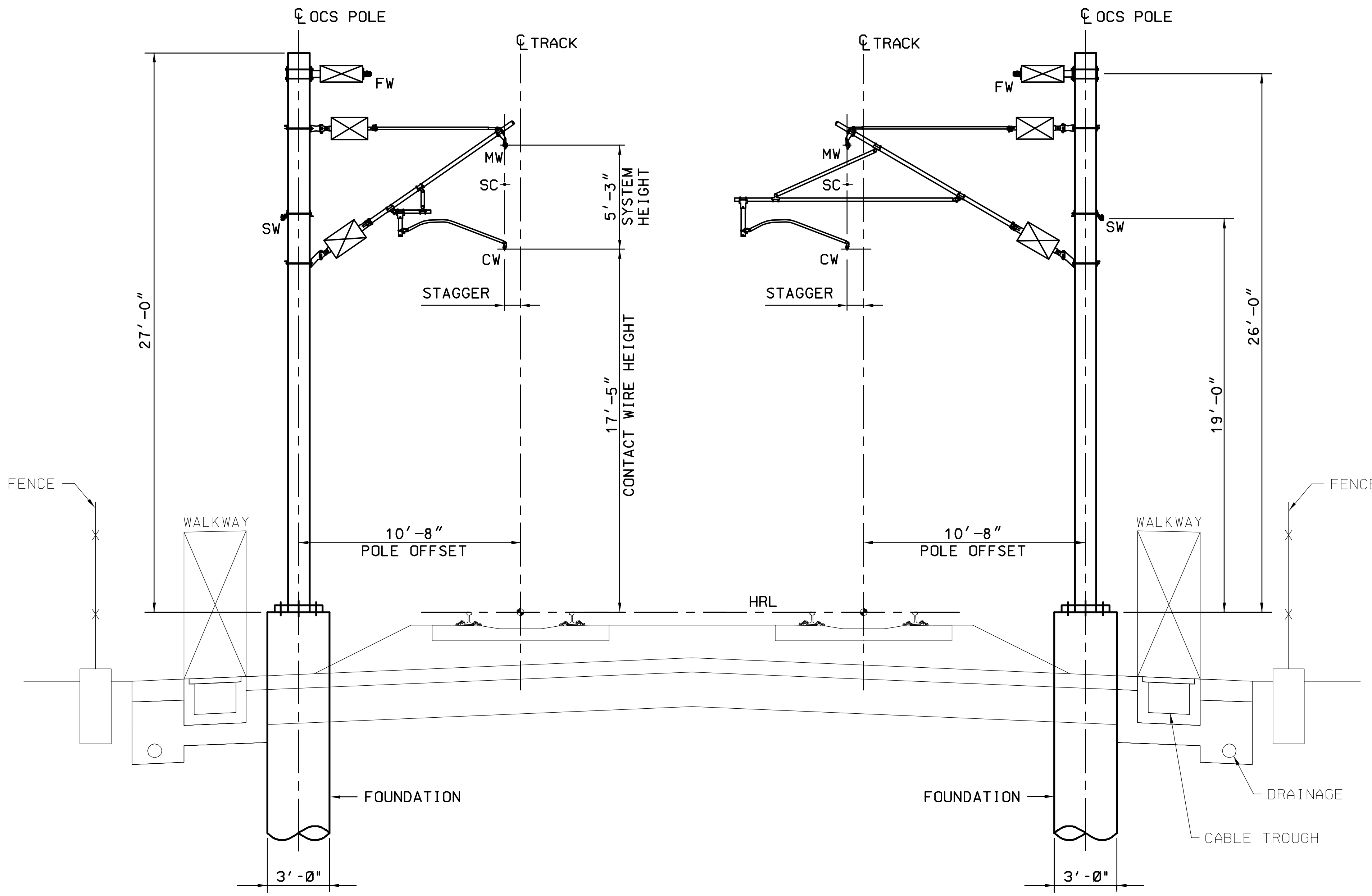
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 CATERARY FREE RUNNING CHART
FOR OVERHEAD BRIDGE
SPEED UP TO 125 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-U
SCALE NTS
SHEET NO.



TYPICAL OCS SUPPORT STRUCTURE
TANGENT TRACKS IN OPEN ROUTE

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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

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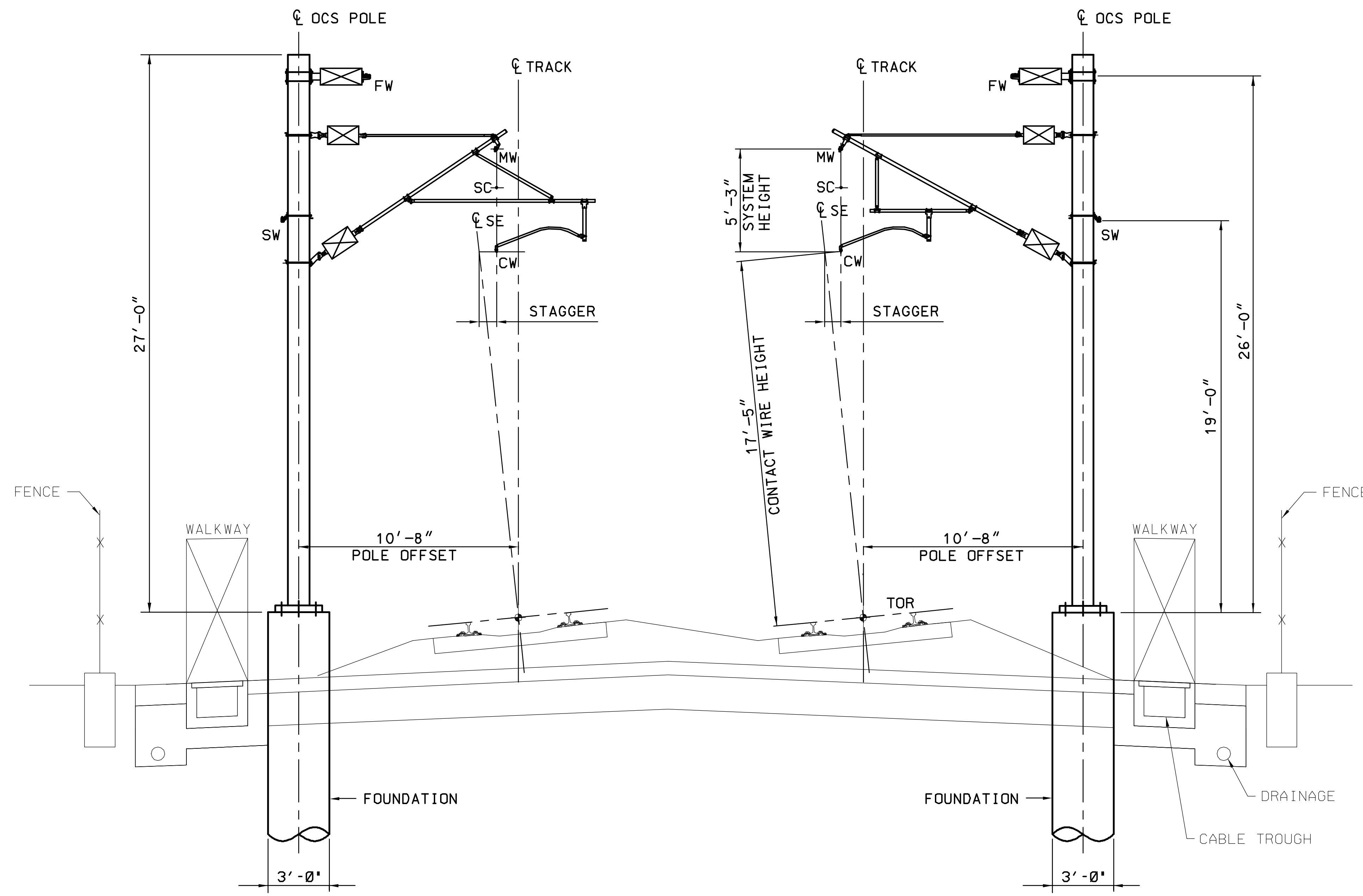
IN CHARGE K. JONG
DATE OCT. 2010

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
FOR TWO TANGENT TRACKS IN OPEN ROUTE
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AA
SCALE NTS
SHEET NO.



TYPICAL OCS SUPPORT STRUCTURE
CURVED TRACKS IN OPEN ROUTE

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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

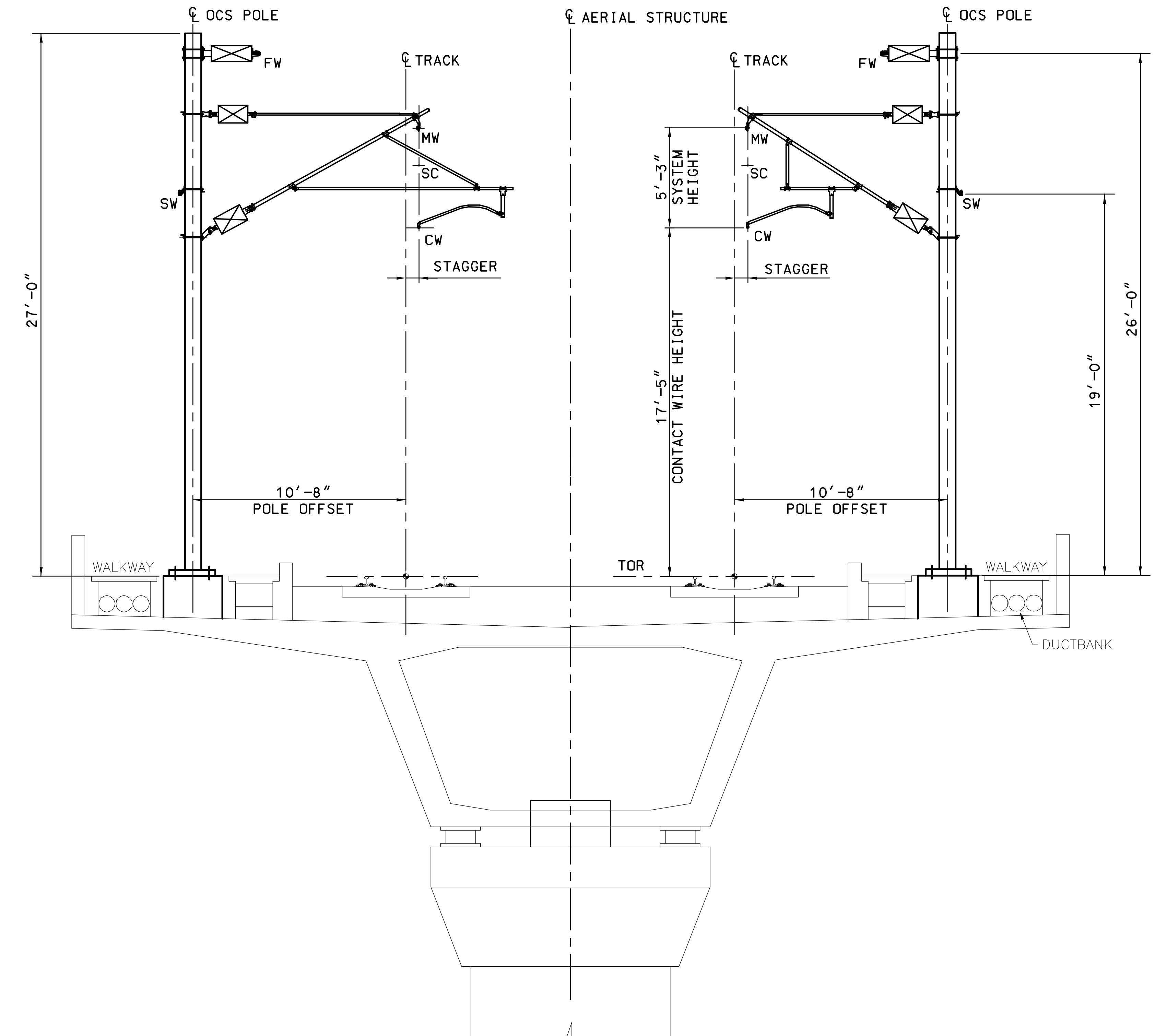
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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
FOR TWO CURVED TRACKS IN OPEN ROUTE
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AB
SCALE NTS
SHEET NO.



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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR AERIAL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
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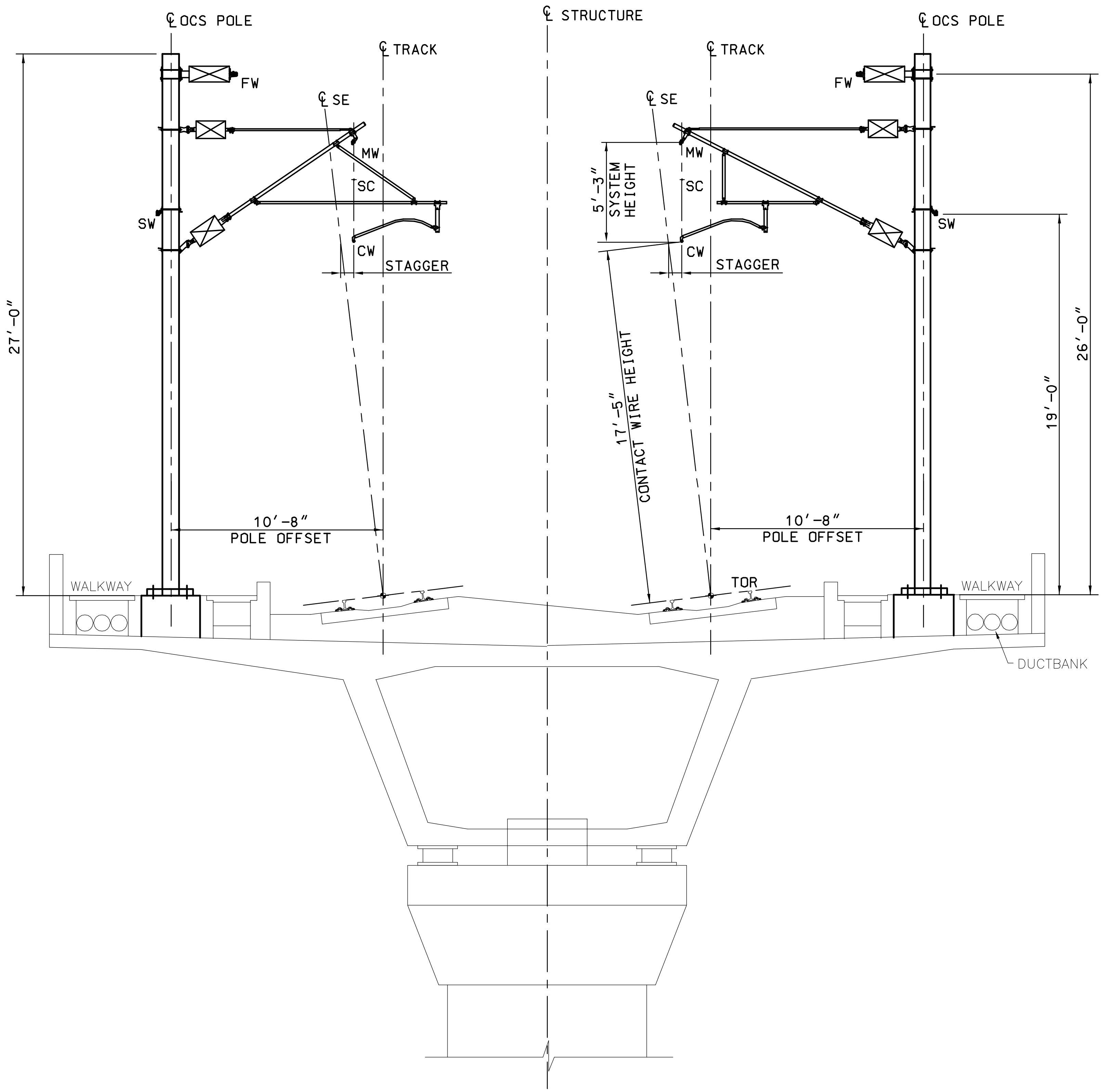
CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS SUPPORT STRUCTURE
ON VIADUCT - TANGENT TRACKS
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AC
SCALE NTS
SHEET NO.



TYPICAL OCS SUPPORT STRUCTURE
ON VIADUCT - CURVED TRACK

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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR AERIAL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

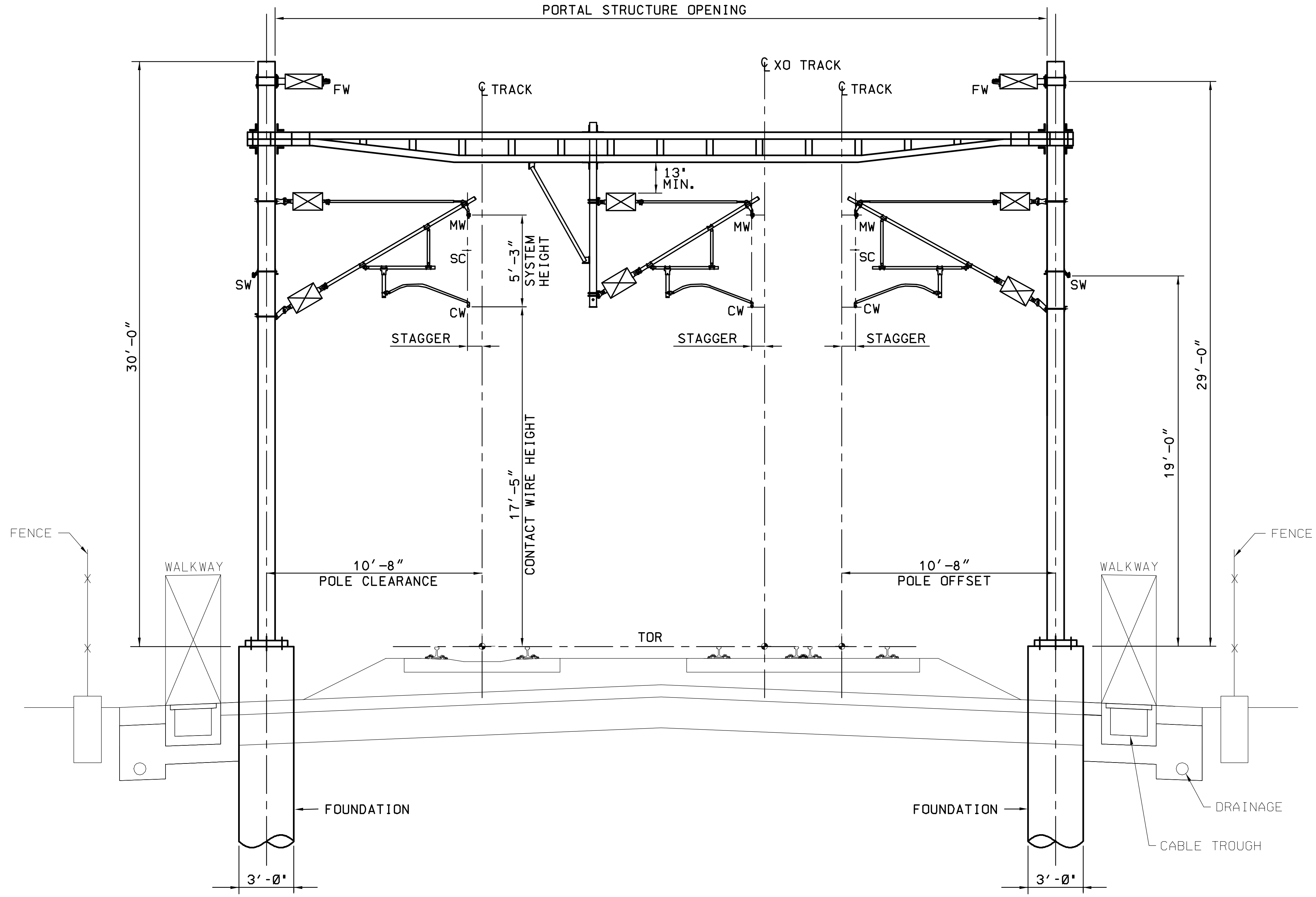
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 - CURVED TRACKS
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AD
SCALE NTS
SHEET NO.



TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
TANGENT TRACK WITH TURNOUT

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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

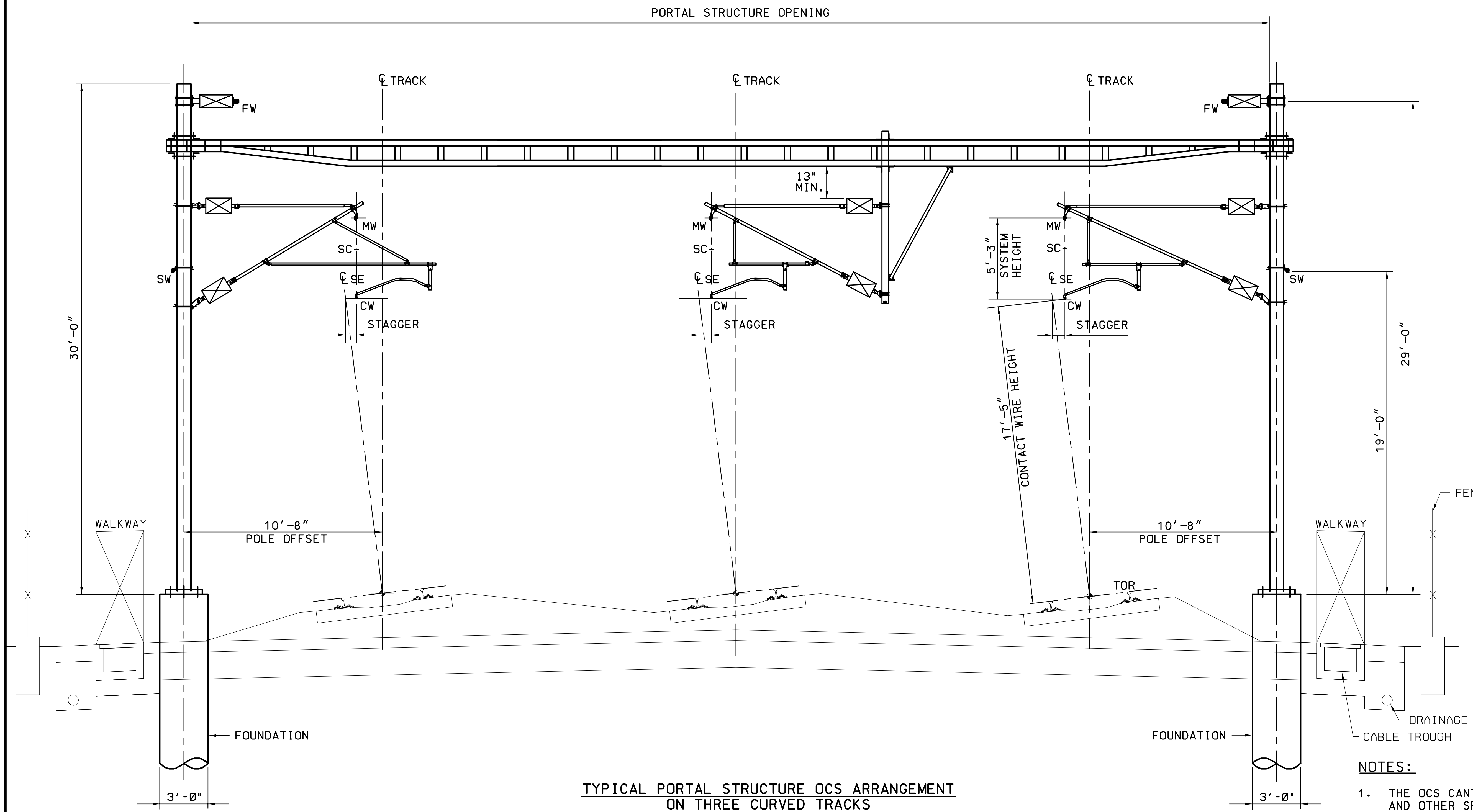
PB PARSONS BRINCKERHOFF

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

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
TANGENT TRACK WITH TURNOUT
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AE
SCALE NTS
SHEET NO.

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



TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
ON THREE CURVED TRACKS

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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.

2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

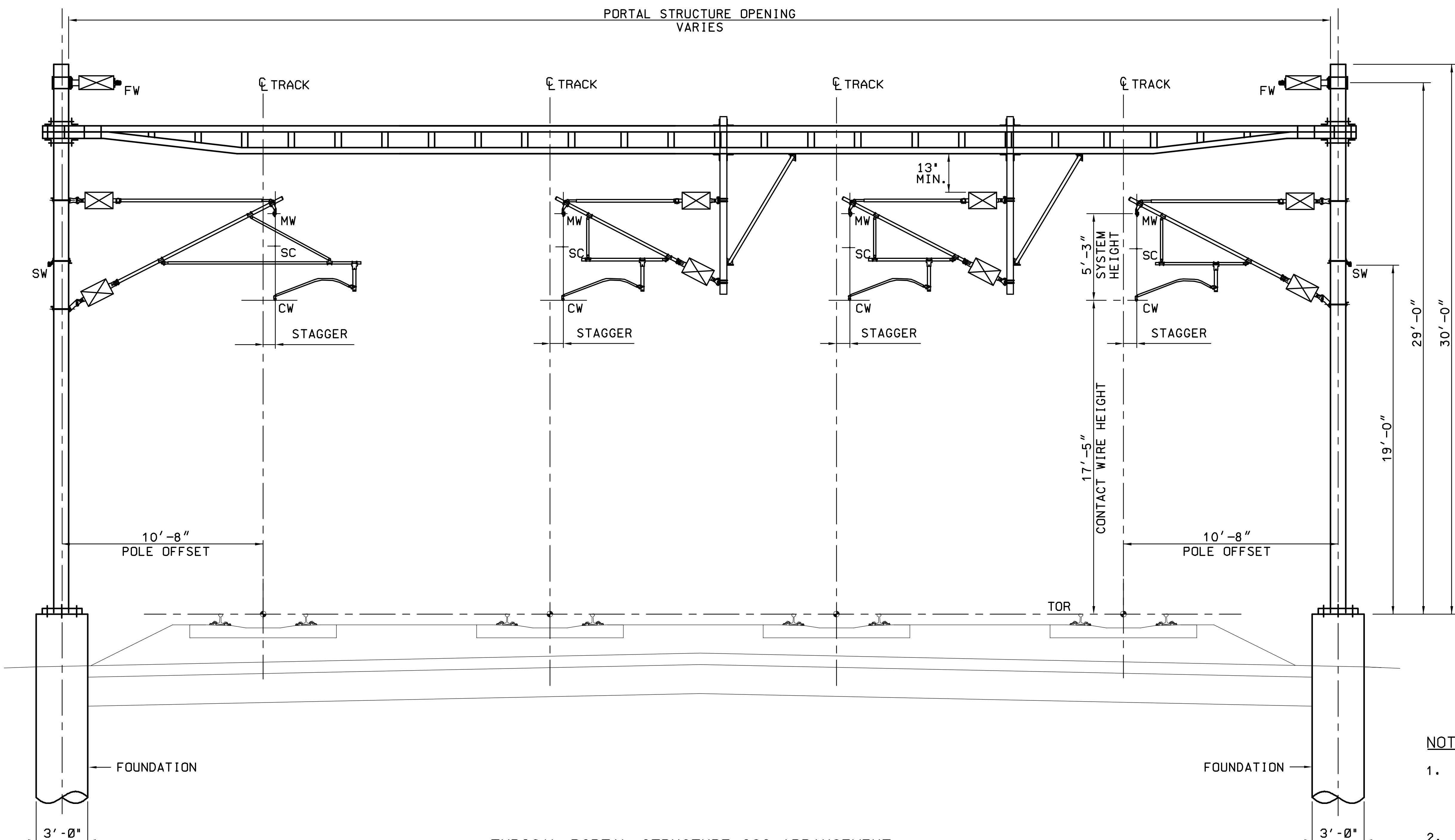
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 PORTAL STRUCTURE OCS ARRANGEMENT
ON THREE CURVED TRACKS
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AF
SCALE NTS
SHEET NO.



TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
ON MULTIPLE TANGENT TRACKS

LEGEND:

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

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

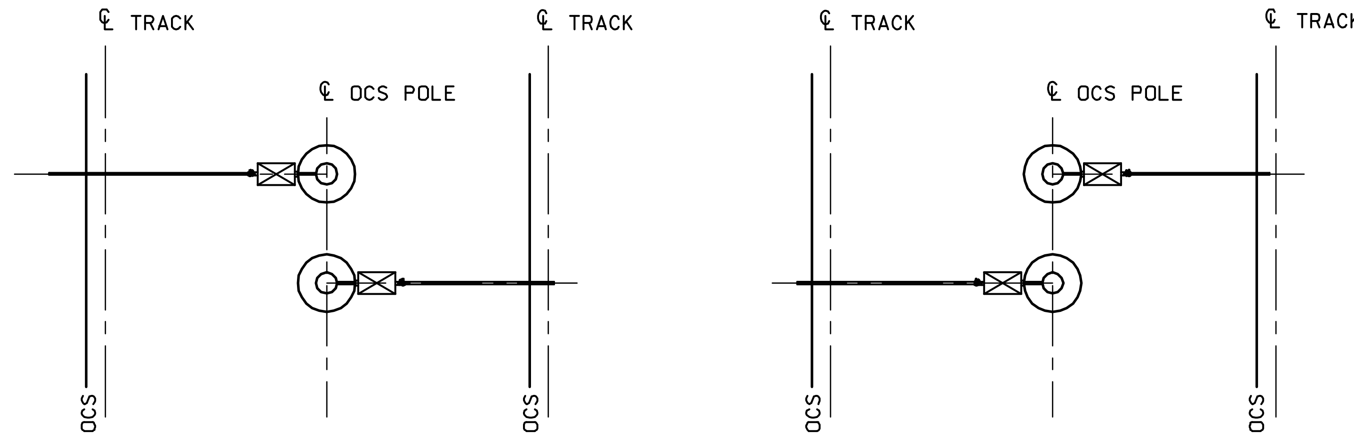
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL PORTAL STRUCTURE OCS ARRANGEMENT
ON MULTIPLE TANGENT TRACKS
SPEED UP TO 220 MPH

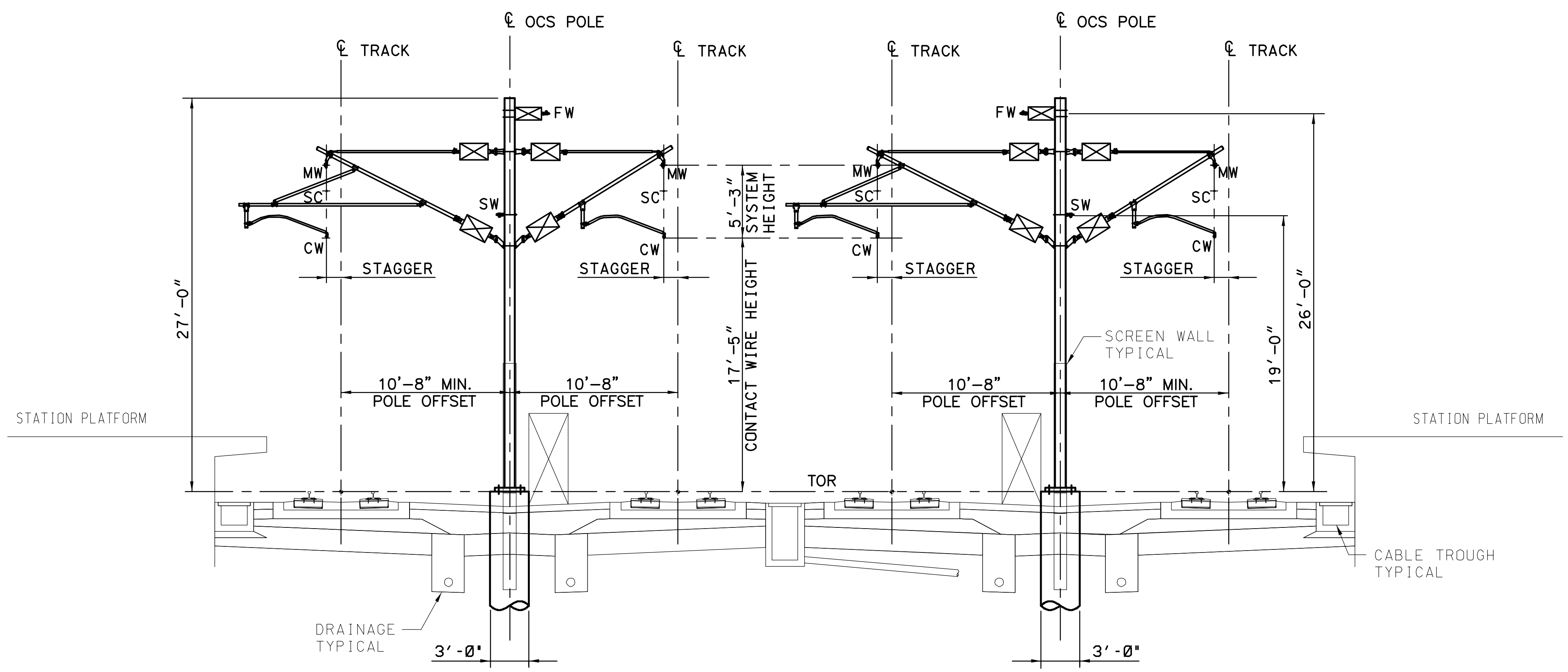
CONTRACT NO.
DRAWING NO. TM 3.2.1-AG
SCALE NTS
SHEET NO.

LEGEND:

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



OCS PLAN VIEW



TYPICAL OCS SUPPORT STRUCTURES
4-TRACK INTERMEDIATE STATION
OUTSIDE BOARDING PLATFORMS

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. THE OCS SUPPORT ARRANGEMENT USING SINGLE CANTILEVERS ON SEPARATE CENTER POLES OR BACK-TO BACK CANTILEVERS ON A COMMON CENTER POLE SHALL BE CONFIRMED BY THE FINAL SYSTEM DESIGNER BASED ON OCS DYNAMIC SIMULATIONS.
3. FOR TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PB PARSONS BRINCKERHOFF

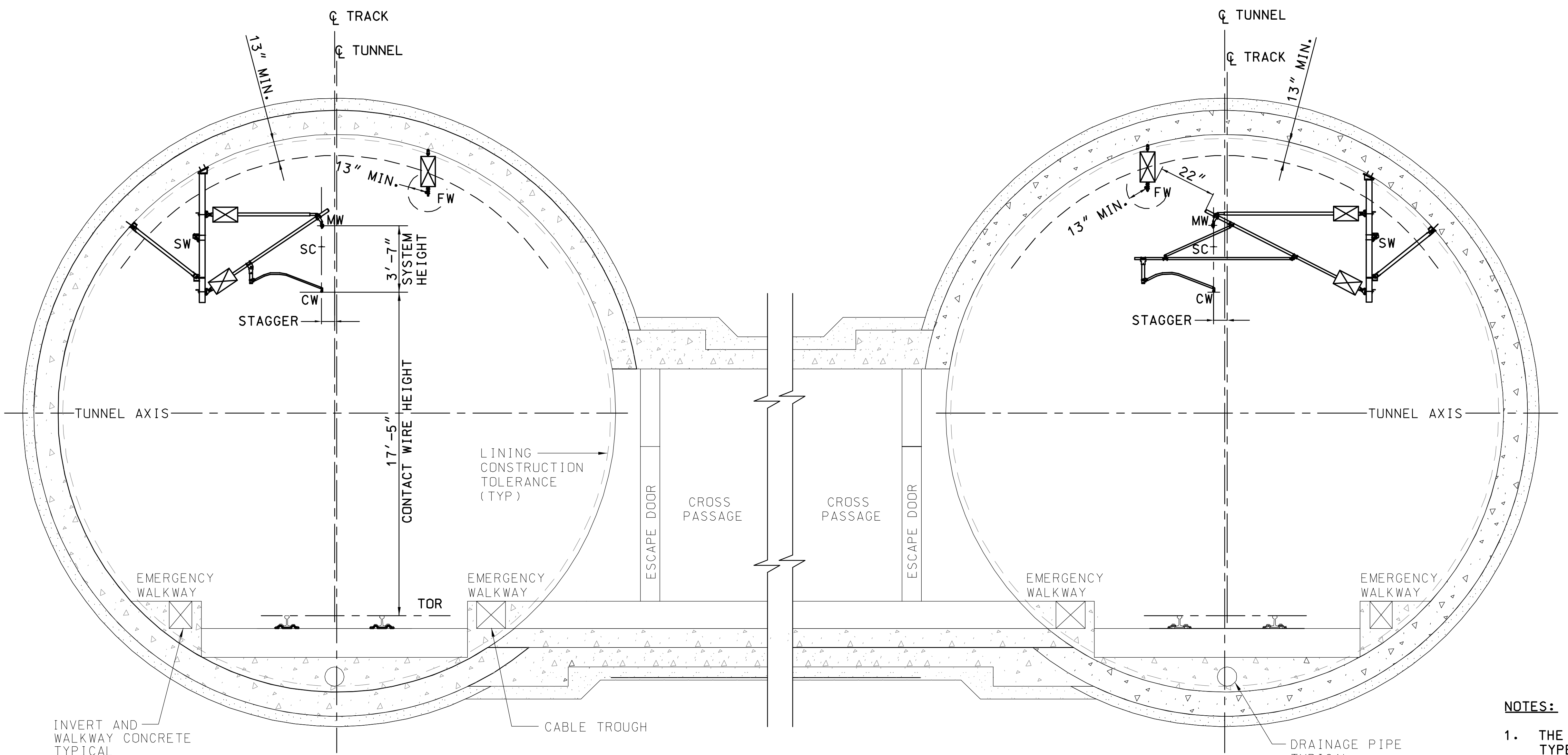
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OCS SUPPORT STRUCTURE
FOR FOUR TRACKS INTERMEDIATE STATION
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AH
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE



TYPICAL CIRCULAR TUNNEL OCS ARRANGEMENT
TANGENT TRACK

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25kV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY 25 KV LIVE PARTS.
4. FOR CIRCULAR TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

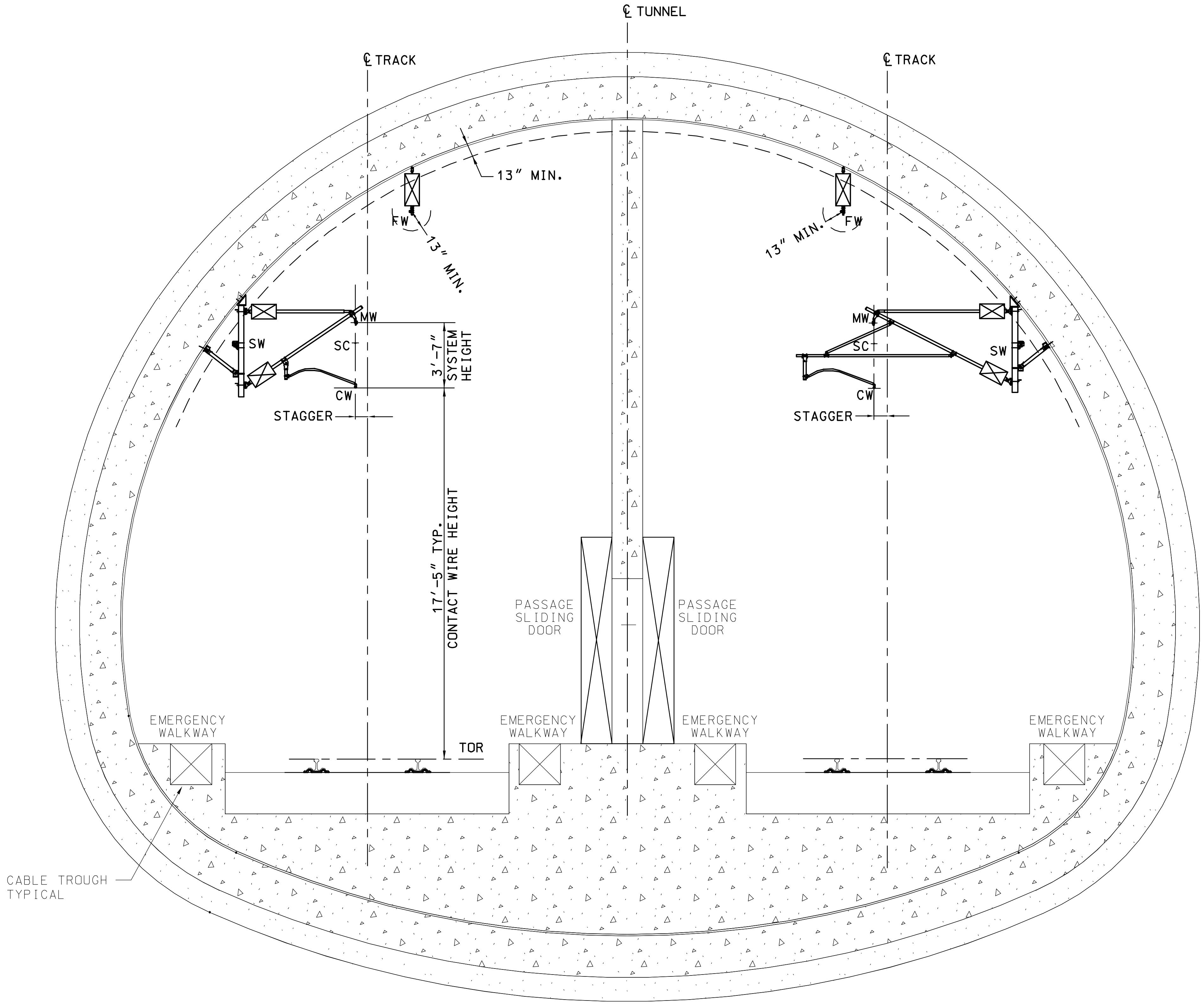
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 CIRCULAR TUNNEL OCS ARRANGEMENT
TANGENT TRACK
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AI
SCALE NTS
SHEET NO.



TYPICAL MINED TUNNEL OCS ARRANGEMENT
TANGENT TRACK

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
SC	STITCH CABLE

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25 KV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY LIVE 25 KV PARTS.
4. FOR MINED TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

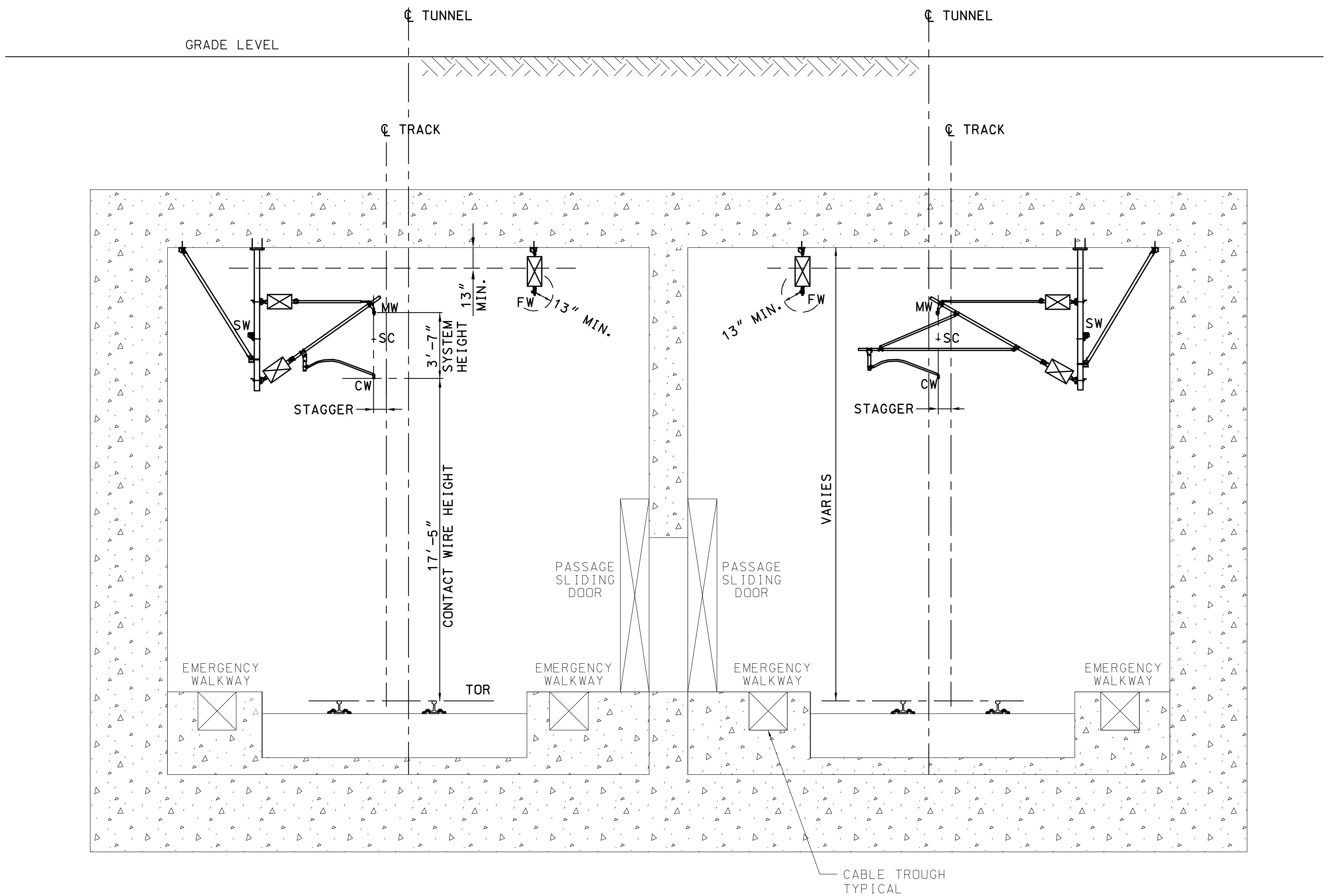
CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

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

CONTRACT NO.
DRAWING NO. TM 3.2.1-AJ
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE



TYPICAL CUT AND COVER TUNNEL OCS ARRANGEMENT
TANGENT TRACK

NOTES:

1. THE OCS TUNNEL CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. 13" MINIMUM ELECTRICAL CLEARANCE BETWEEN LIVE 25 KV AND GROUNDED PART OF STRUCTURE.
3. 22" MINIMUM ELECTRICAL CLEARANCE BETWEEN NEGATIVE FEEDER AND ANY LIVE 25 KV PARTS.
4. FOR CUT AND COVER TUNNEL TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

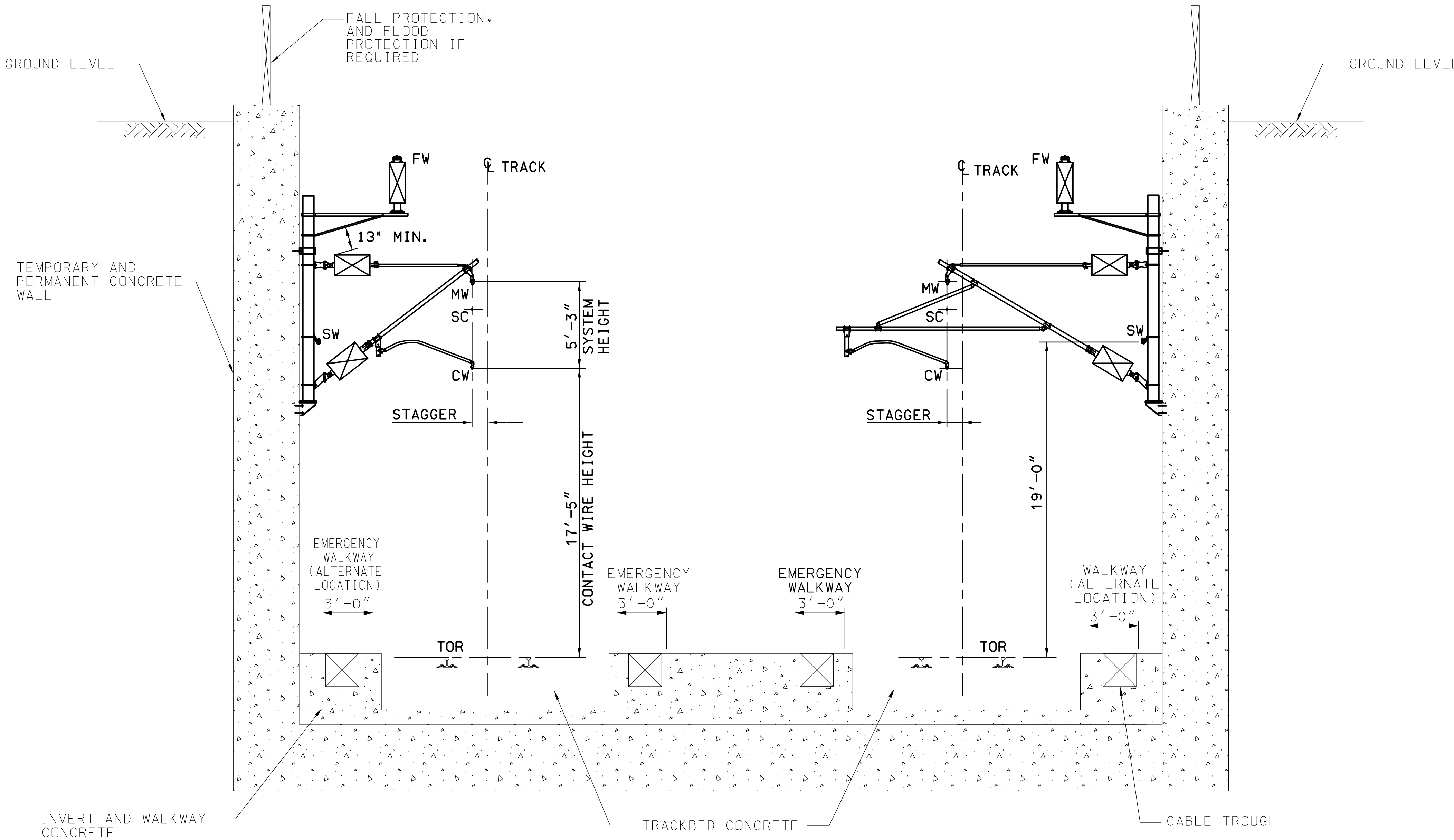
DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 EQUIPMENT FOR
CUT AND COVER TUNNEL - TANGENT TRACK
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AK
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL OCS SUPPORT STRUCTURES
OPEN TRENCH ON TANGENT TRACKS

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

PARSONS BRINCKERHOFF

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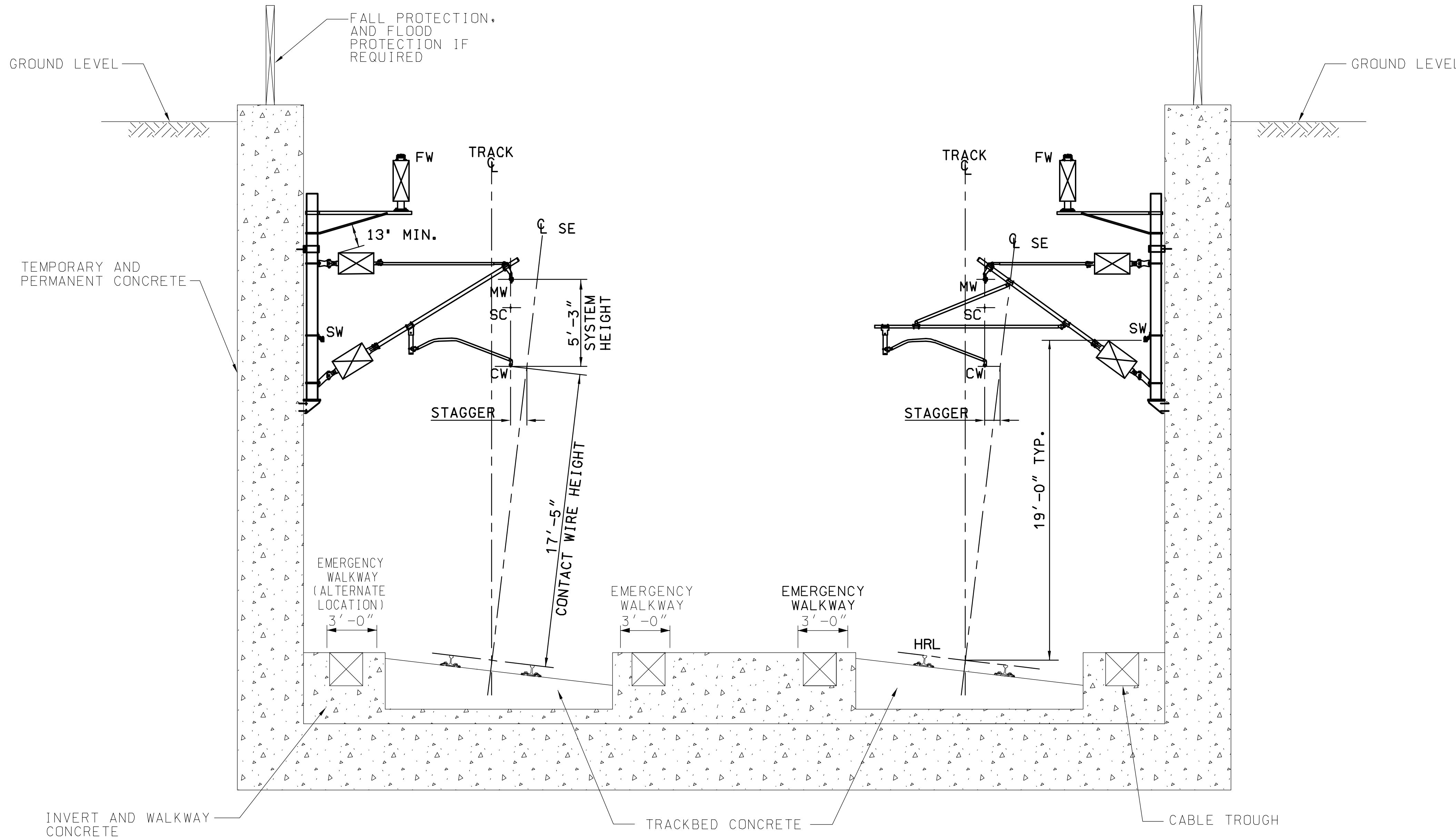
CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS STRUCTURE
ON TANGENT TRACKS
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AL
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE

TYPICAL OCS SUPPORT STRUCTURES
OPEN TRENCH ON CURVE TRACKS

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
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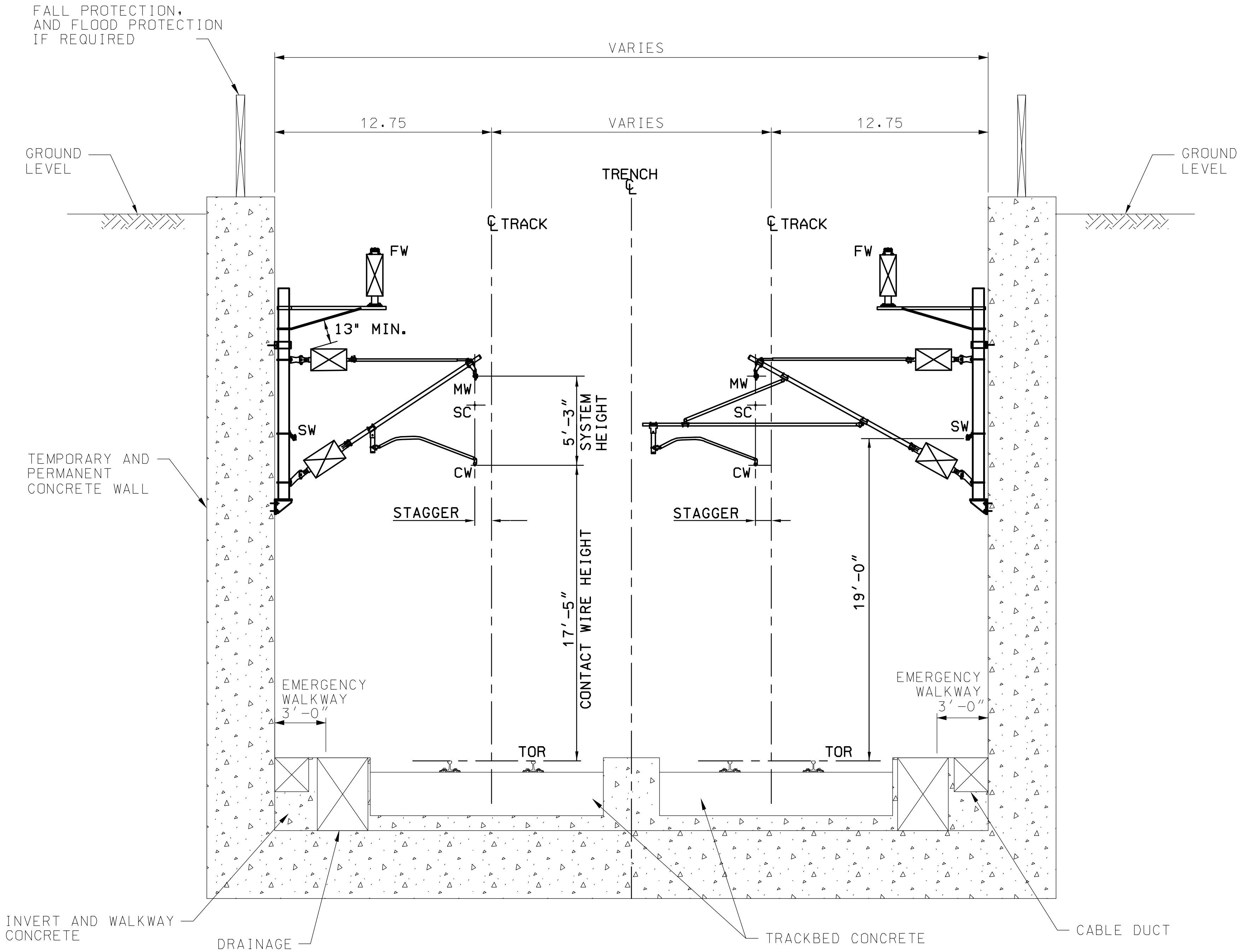
DATE OCT. 2010

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 OPEN TRENCH OCS STRUCTURE
ON CURVE TRACKS
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AM
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL OCS SUPPORT STRUCTURES
OPEN TRENCH TANGENT TRACK WITH WALL MOUNTED SUPPORT

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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CALIFORNIA HIGH-SPEED RAIL AUTHORITY
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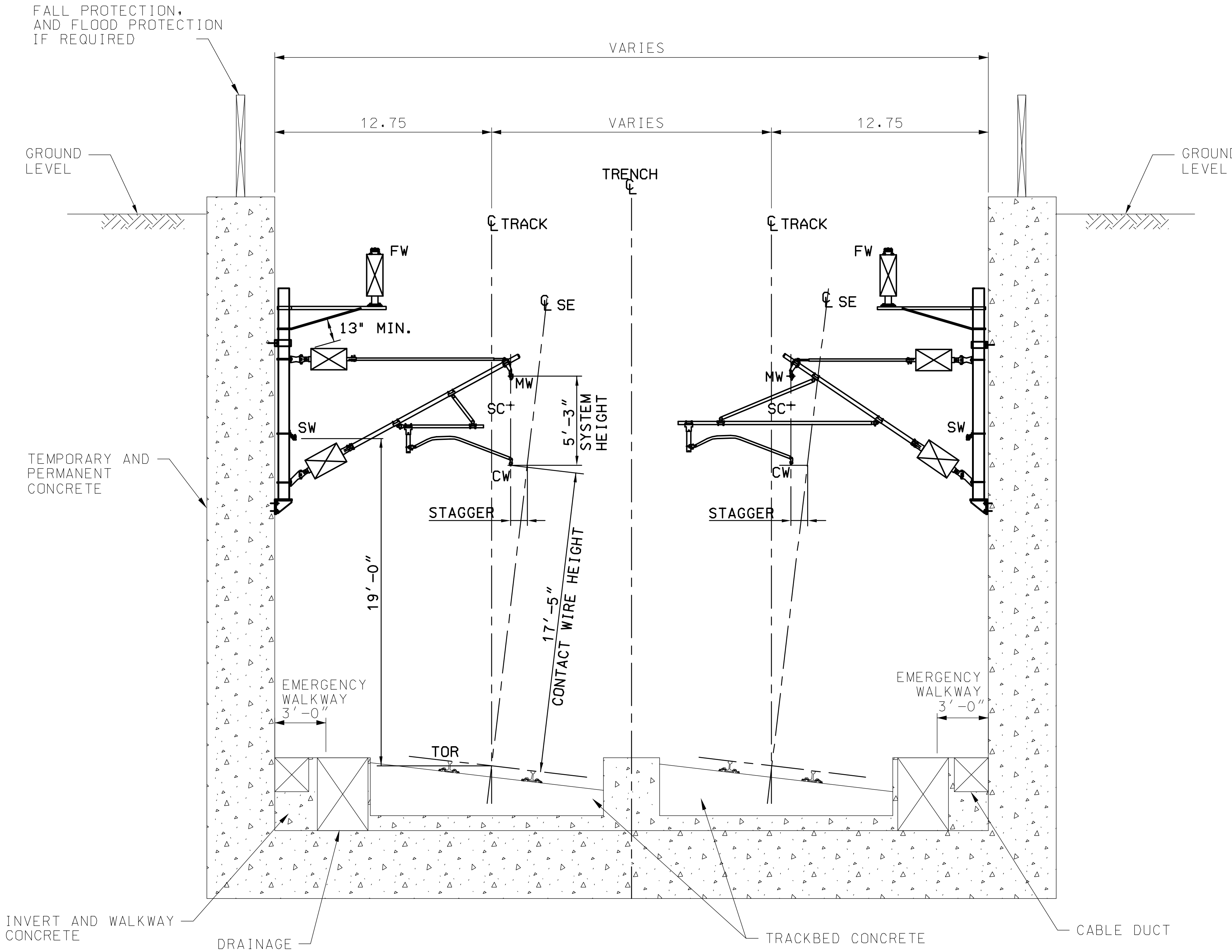
CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS STRUCTURE
WALL MOUNTED SUPPORT TANGENT TRACK
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AN
SCALE NTS
SHEET NO.



TYPICAL OCS SUPPORT STRUCTURES
OPEN TRENCH 2 CURVED TRACK WITH WALL MOUNTED SUPPORT

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
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

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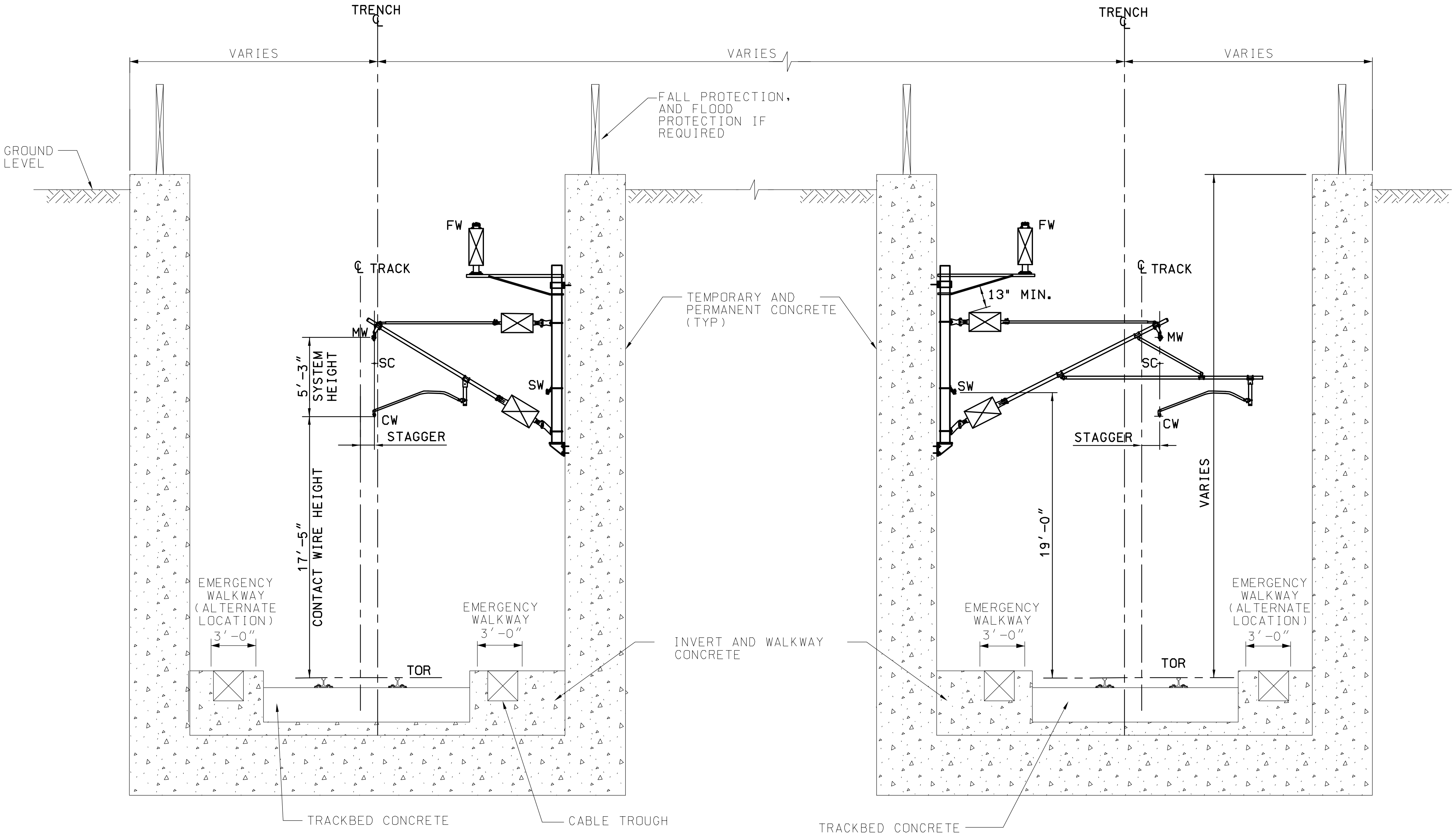
FLY CALIFORNIA Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS STRUCTURE
WALL MOUNTED SUPPORT CURVED TRACK
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AO
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.

2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

TYPICAL SINGLE TRACK OPEN TRENCH STRUCTURE
OCS WALL MOUNTED SUPPORT 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 OCT. 2010

PB PARSONS BRINCKERHOFF

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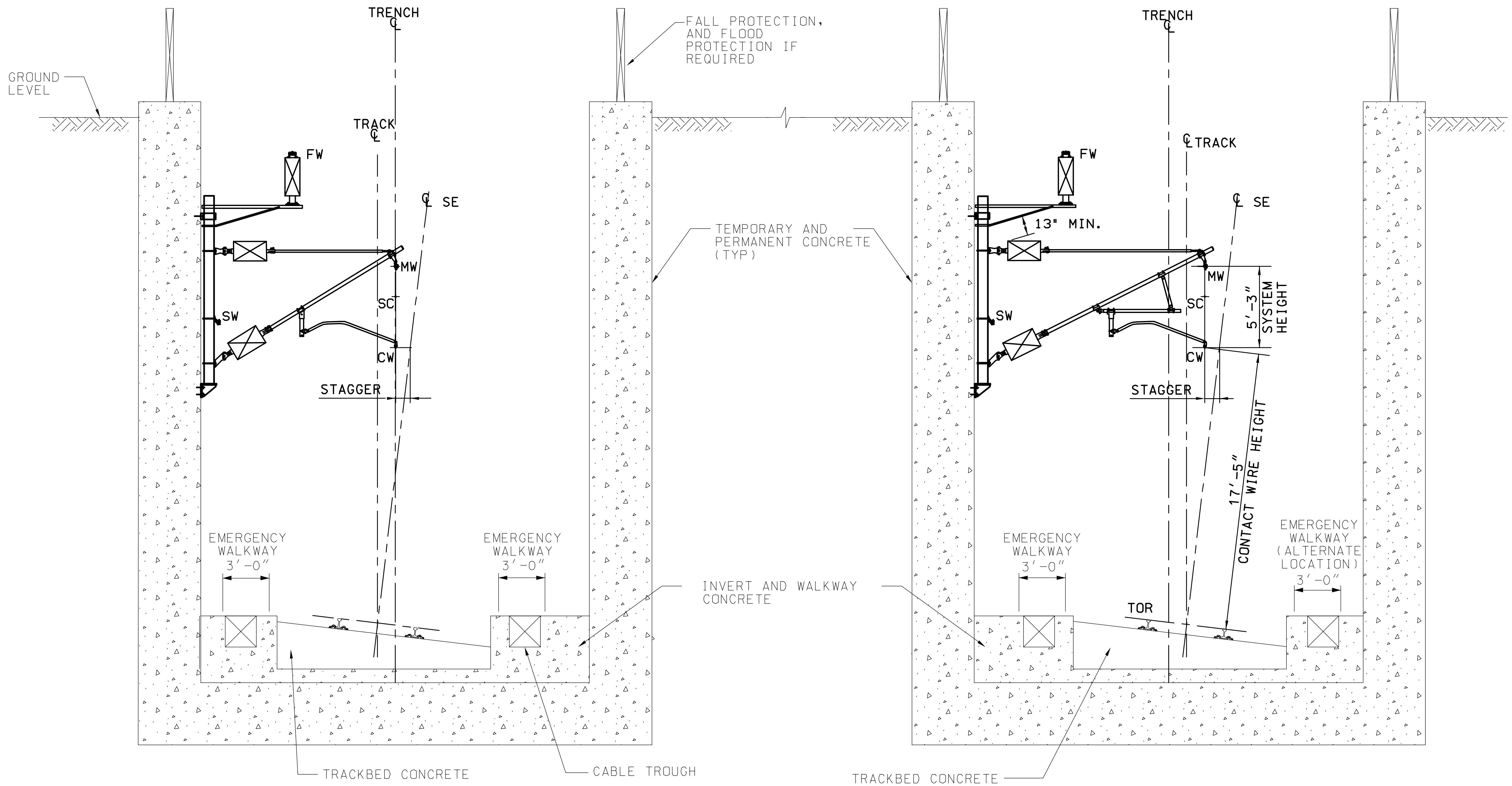
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT
OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL SINGLE TRACK OPEN TRENCH STRUCTURE
OCS WALL MOUNTED SUPPORT TANGENT TRACK
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AP
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
℄	CENTERLINE
TOR	TOP OF RAIL
SC	STITCH CABLE



TYPICAL SINGLE TRACK OPEN TRENCH STRUCTURES
OCS WALL MOUNTED SUPPORT ON CURVED TRACK

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE OCT. 2010

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 SINGLE TRACK OPEN TRENCH STRUCTURE
ON WALL MOUNTED SUPPORT ON CURVED TRACK
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AQ
SCALE NTS
SHEET NO.

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

LEGEND:

FW	NEGATIVE FEEDER WIRE
SW	STATIC WIRE
MW	MESSENGER WIRE
CW	CONTACT WIRE
SE	TRACK SUPERELEVATION
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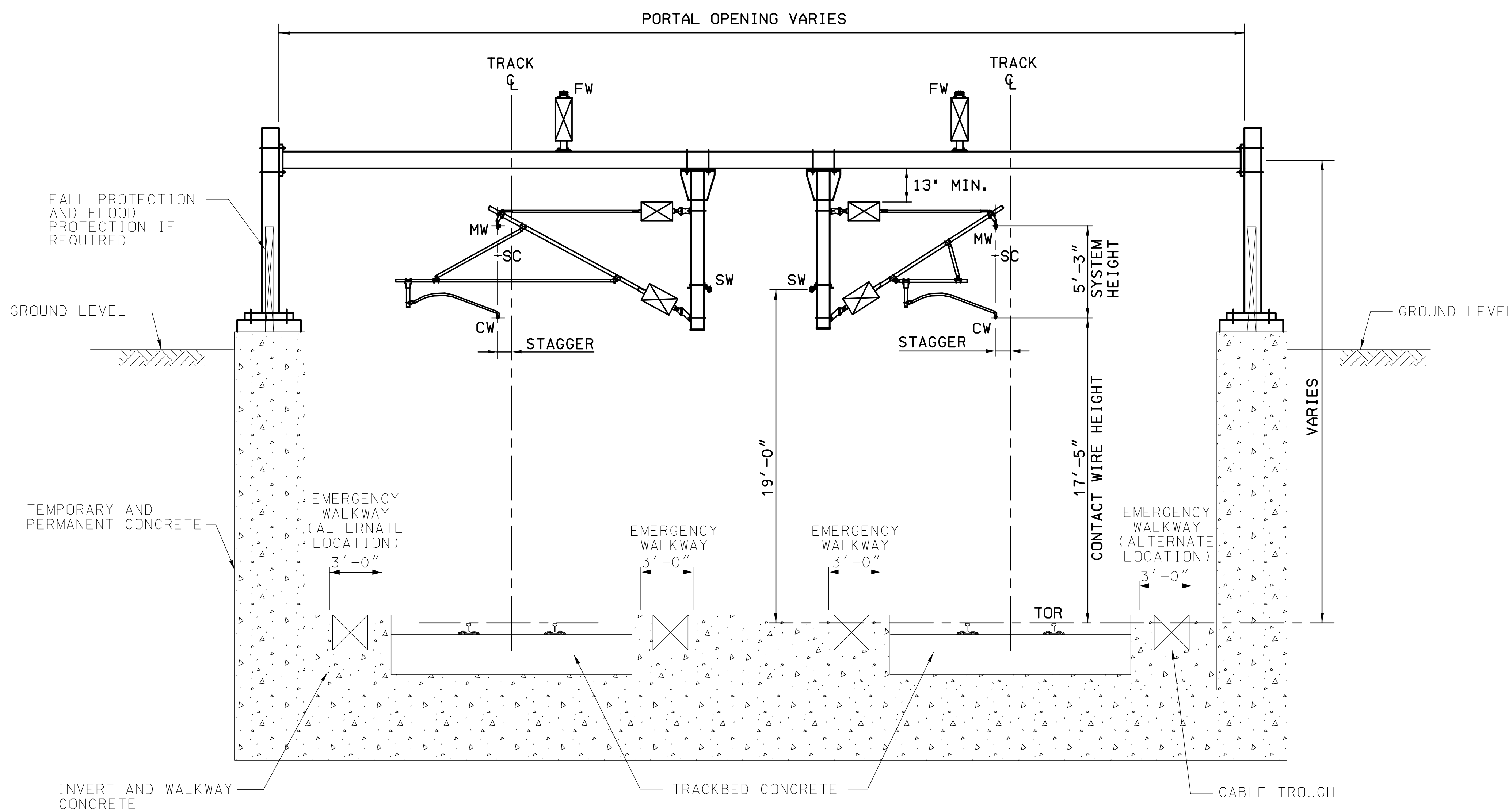

TYPICAL OPEN TRENCH OCS STRUCTURES
TANGENT TRACKS ON PORTAL STRUCTURE

NOTES:

1. THE OCS CANTILEVER CONFIGURATION TYPES AND OTHER SPECIFICS OF THE ITEMS IN THIS DIRECTIVE DRAWING SHALL BE DETERMINED BY THE FINAL DESIGNER.
2. FOR OPEN TRENCH TRACK CROSS SECTION DETAILS REFER TO INFRASTRUCTURE DIRECTIVE DRAWINGS.

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

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY M. HSIAO
DRAWN BY J. LAU
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OVERHEAD CONTACT SYSTEM
DIRECTIVE DRAWING
TYPICAL OPEN TRENCH OCS STRUCTURE
PORTAL STRUCTURE TANGENT TRACKS
SPEED UP TO 220 MPH

CONTRACT NO.
DRAWING NO. TM 3.2.1-AR
SCALE NTS
SHEET NO.