California High-Speed Train Project

TECHNICAL MEMORANDUM

Grounding and Bonding Requirements For Train Control and Communications

TM 3.3.4

Prepared by: *Signed document on file* — 08 Jun 10
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Released by: *Signed document on file* — 11 Jun 10
Anthony Daniels, Program Director — Date

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

Prepared by PB 125 YEARS
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 memoranda. 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 Richard Schmedes	DD Month YY Date
Infrastructure:	*Signed document on file* John Chirco	6 Jun 10 Date
Operations:	*Signed document on file* Paul Mosier	9 Jun 10 Date
Maintenance:	*Signed document on file* Paul Mosier	9 Jun 10 Date
Rolling Stock:	*Signed document on file* Frank Banko	4 Jun 10 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. Between Anaheim and Los Angeles and on the Caltrain corridor the proposed California High-Speed Train (CHST) will operate within a shared right-of-way and possibly with shared tracks with conventional passenger railroads and freight (temporally separated).

The 25 kV overhead contact system has key considerations to be made with respect to grounding and bonding of train control equipment and housings as well as the rails themselves for both personnel safety and proper operation of the Train Control and Communications (TCC) system. These considerations require an interface to the traction power and Overhead Contact System (OCS) subsystems in connection with grounding and bonding of the rails. It is therefore necessary to coordinate these requirements between the three subsystems to ensure that the electrical hazards are correctly mitigated but without adversely affecting the reliable operation of the TCC equipment including track circuits.

The purpose of this technical memorandum (TM) is to recommend appropriate standards and best practices to define criteria for the grounding and bonding requirements for train control and communications for the California High Speed Train Project. The following topics are addressed in this TM:

- Provide a general system description and define the general topics of the grounding and bonding requirements
- Define the general grounding and bonding requirements
- Define the interface with the Traction Electrification System (TES) grounding and bonding requirements
- Provide the summary and design criteria for the grounding and bonding requirements for train control and communications

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 train control and communications grounding and bonding requirements for the California High Speed Train Project to:

- Provide a general system description and define the general grounding and bonding requirements of the train control and communications systems
- Define the interface with the Traction Electrification System (TES) grounding and bonding requirements for the California High Speed Train Project (CHSTP)

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

This memorandum presents data relating to the design of the train control and communications systems grounding and bonding requirements that must be satisfied. It is based on present U.S. Federal and State Orders, guidelines, and practices where available. Document searches were conducted to identify definitive criteria to be used for the CHSTP application and, in some cases, data were not available. Present practices for high speed railways were reviewed and used to define criteria for the CHST project that are incorporated in this memorandum.

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

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

1.2 STATEMENT OF TECHNICAL ISSUE

The high speed trains are powered by an Overhead Contact System (OCS) energized at 25 kV 60 Hz. In order to provide for a return current for the traction power the rails need to be connected to the power distribution system. For broken rail detection a system of track circuits insulated from each other is installed on the track. Impedance bonds are installed to couple the traction return currents around the insulation between the track circuits. At regular intervals the rails are connected together and to the static wire which provides grounding protection. In addition, at traction power facilities approximately five miles apart along the right-of-way the rails need to be connected to the center taps of the winding of the autotransformers that are used for the efficient supply of traction energy to the OCS. For personnel safety it is necessary to connect the rails to ground, however, in order to retain the ability for the track circuits to detect broken rails, limitations are necessary in the distance between connections from the rails to ground and from the rails on one track to the rails on another track. This Technical Memorandum will establish these limits.

Train control housings and facilities need to be connected to ground for equipment and personnel safety. This Technical Memorandum will describe the methods for connecting train control housings and facilities to ground.

Communications facilities and equipment need to be connected to ground for both equipment and personnel safety and to assure proper operation of the communications system. This Technical Memorandum will describe the methods for connecting communications housings and facilities to ground.

Grounding requirements for personnel safety are described in TM 3.2.6 TES Requirements for Grounding and Bonding and Protection from Electric Shock. Modifications to the requirements shown in TM 3.2.6 concerning train control and communications are described herein.

1.2.1 Units

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

2.0 DEFINITION OF TECHNICAL TOPIC

2.1 GENERAL

2.1.1 CHSTP Design Considerations

There are several different and to some extent competing requirements that need to be met in connection with grounding and bonding for the train control and communications systems

- Passenger Safety
- Personnel Safety
- Broken Rail Detection
- Reliable Train Control and Communications Operation
- Low Loss Traction Power Return

2.1.2 CHSTP Design Parameters

The grounding system shall be designed to protect equipment and facilities, and to prevent electric shocks being received by passengers and personnel. Protection for passengers on-board the trains will be provided by the Rolling Stock requirements. Protection for passengers at stations or terminals on the platforms or within the facilities will be provided by the Traction Electrification System design and the building designs at the stations. These requirements are shown in the TES Grounding and Bonding Requirements.

Protection for personnel to assure that at no time do operating or maintenance personnel receive unacceptable electrical shocks is provided by adhering to TM 3.2.6 TES Requirements for Grounding and Bonding and Protection from Electric Shock. TM 3.2.6 follows EN 50122-1: 1998 and delineates the maximum safe rail touch voltage and steps required to be taken to ensure that these safe limits are not exceeded under both normal as well as fault conditions. The grounding and bonding of housings and wayside apparatus not attached to rails will provide protection for equipment within the housing and personnel who need to come into contact with these facilities. Train control and communications facilities integral to a station will utilize the station ground grid to furnish this protection. Train control and communications facilities located along the wayside will be connected to ground rods that are designed for a maximum resistance to reference ground of 15 ohms or less for signal facilities and 5 ohms or less for communications facilities, except for signal masts, cantilevers, and bridges, which shall be connected to the static wire or to the neutral leads of impedance bonds as shown herein.

The rules for connections from the rails to prevent rail voltages to ground exceeding the permissible values specified in TM 3.2.6 without sacrificing broken rail detection are defined within this document.

2.2 LAWS AND CODES

Initial high-speed train (HST) design criteria will be issued in technical memoranda that provide guidance and procedures to advance the preliminary engineering. When completed, a Design Manual will present design standards and criteria specifically for the design, construction and operation of the CHSTP’s high-speed railway.

Criteria for design elements not specific to HST operations will be governed by existing applicable standards, laws and codes. Applicable local building, planning and zoning codes and laws are to be reviewed for the stations, particularly those located within multiple municipal jurisdictions, state rights-of-way, and/or unincorporated jurisdictions.

In the case of differing values, the standard followed shall be that which results in the satisfaction of all applicable requirements. In the case of conflicts, documentation for the conflicting standard is to be prepared and approval is to be secured as required by the affected agency for which an exception is required, whether it be an exception to the CHSTP standards or another agency standards.

2.2.1 Federal Requirements

Title 47 of the Code of Federal Regulations (CFR) regulates radio communications. There is no requirement in Title 47 governing grounding or bonding.

Title 49 of the CFR governs rail transportation. It provides standards for compliance with the Americans with Disabilities Act and with safety of rail transportation. .

2.2.2 State Requirements

Compliance with requirements of the State of California that impact grounding and bonding is addressed in TM 3.2.6 TES Requirements for Grounding and Bonding and Protection from Electric Shock.

2.2.3 Local Codes

Compliance with requirements of local codes that impact grounding and bonding is addressed in TM 3.2.6 TES Requirements for Grounding and Bonding and Protection from Electric Shock.

3.0 ASSESSMENT / ANALYSIS

The following sections address the different requirements for bonding and grounding of the train control and communications subsystems and highlight areas where bonding and grounding requirements for the traction power and OCS subsystems may conflict. They also address the mitigation required to resolve the conflict.

Consideration of the TCC subsystem requirements has been based upon the requirements of Amtrak's Electrified Territory Instructions for Cross-Bonding and Structure Grounding and Related Instructions For Electric Traction Employees Grounding OCS and For C&S Employees Maintaining Track Circuits.

3.1 GENERAL

The requirements given in TM 3.2.6 TES Requirements for Grounding and Bonding and Protection from Electric Shocks shall be followed, except as described herein.

3.2 RAIL CONNECTIONS TO GROUND

A study was performed of step and touch potentials that would result under worst case conditions with grounding to the rail only at traction power facilities that will be located approximately 5 miles apart. This study demonstrated that unacceptably high voltages up to 347 volts could be expected. A further study is in progress to ascertain the minimum number of additional connections to ground required to ensure that rail touch potentials remain within permissible limits (80 V for 1 second, 65 V for periods from 1 second to 5 minutes, and 60 V for any period over 5 minutes). In anticipation of the outcome of this study it has been tentatively decided to ground the rail at no more than 12,000-foot (intervals. This decision will be reviewed based on the results of the abovementioned study.

3.3 CROSS-BONDING

Plans TM 3.3.4 A-D demonstrate the impedance bond requirements enumerated below.

3.3.1 Definition of types of impedance bond connections (TM 3.3.4 - A)

An "**A**" point is defined as a location where impedance bond neutral leads on all tracks are bonded together, to OCS support structures which are in turn bonded to the static return wires and, at traction power facilities such as substations, switching stations, and paralleling stations, directly to the traction power facility return bus.

A drain bond is an impedance bond installed in order to connect the rails to traction power facilities such as substations, switching stations, and paralleling stations where no insulated joints exist in the vicinity of the traction power facility. At such locations the neutral leads of the drain bonds are connected directly to the traction power facility return bus.

A "**C**" point is defined as a location with impedance bonds to bypass insulated joints on one track but with no cross-bonding.

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3.3.2 Distance between types of impedance bond connections (TM 3.3.4 - B)

Cross-bond locations ("A" points) must include a minimum of two (2) track circuits between them and should, if practical, be located not less than 6,000 feet nor more than 12,000 feet apart.

3.3.2.1 For cross-bond locations over 6,000 feet apart:

- Distance between cross-bond locations should be not less than 167% of the length of the longest track circuit, any portion of which lies between the cross-bond points.
- Conversely, the total length of any track circuit, any portion of which is between the cross-bond points, should not exceed 60% of the distance between the cross-bond points

- The ideal arrangement would be two equal length track circuits between cross-bond points, each 50% of the total distance between them.

3.3.2.2 For cross-bond locations less than 6,000 feet apart:

- There must be a minimum of three (3) track circuits between the cross-bond locations ("A" or points).
- Distance between cross-bond locations must be not less than 250% of the length of the longest track circuit, any portion of which lies between the cross-bond points.
- Conversely, the total length of any track circuit, any portion of which is between the cross-bond points, should not exceed 40% of the distance between the cross-bond points.
- The ideal arrangement would be three equal length track circuits between cross-bond points, each 33-1/3% of the total distance between them. Total distance should be as close to 6,000 feet as possible.
- In no case will a distance of less than 3,000 feet between cross-bond locations ("A" points) be permitted.

The "percent ratio" (minimum of 167% in 3.3.2.1 and minimum of 250% in 3.3.2.2) is calculated for any given section between cross-bond locations ("A" points) as D(XB) divided by D(LTC), where D(XB) is the distance between cross-bond points defining the section and D(LTC) is the length of the longest track circuit in the section.

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

3.3.3 Cross-bonding at interlockings (TM 3.3.4 – C)

Cross-bonding should be placed as close to interlocking crossovers as possible to reduce the possibility of flashover of-insulated joints in crossovers. If possible, an "A" point should be placed at one of the interlocking home signal locations at each interlocking. This must be done consistent with the Rules in 3.3.2 and the need to place an "A" point at each substation, switching station or paralleling station return bus location.

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

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

3.3.4 Cross-bonding in single bore tunnels

Where an “A” point is required within a single bore tunnel the neutral leads of the impedance bonds will be connected to the static return conductor in that bore.

3.3.5 Signals (TM 3.3.4 – D)

The base of a ground-mounted signal mast is to be bonded to the traction return system by direct connection to the neutral leads at the insulated joints adjacent to the signal. There are to be no other electrical connections between the signal mast and other structures or other rails or neutral leads unless specifically called for on the plan as part of an "A" point.

Signal bridges or cantilever structures at a location that is not an "A" point should not be electrically connected to any neutral leads or any portion of any track structure that is part of the signal system. These structures should be aerially connected to the nearest structure that is bonded into the static wire return system, preferably at both ends of any bridge spanning multiple tracks.

3.3.6 Signal Cables

Signal control or lighting cables and switch cables in electrified territory should not have metallic shielding. Metallic messenger or duct must not be used in any way that could cause an electrical interconnection between signals or signal bridges and signal instrument housings.

3.4 COMMUNICATIONS

The purpose of this section is to enable the planning, design, and installation of data communications grounding and bonding systems within a building with or without prior knowledge of the data communications systems that will subsequently be installed. This section also provides recommendations for grounding and bonding of towers and antennas and supports a multivendor, multiproduct environment as well as various system installation practices.

The following equipment requires special attention to proper grounding:

- Optical Ethernet switches and optical to electrical conversion equipment
- Data signaling interfaces such as modems and gateways
- Wayside optical regeneration equipment
- Radio repeaters and antenna including Yard Wi-Fi nodes
- Tower and antenna structures
- CCTV cameras, VMS signs and other field equipment subject to EMI from train and traction power operations

3.4.1 Electrical Considerations for the Grounding of Communications Equipment

All grounding should be in accordance with applicable standards as listed in section 3.4.2 and local codes, except as modified herein. Each piece of equipment shall be grounded in accordance with the recommendations of the manufacturer.

A 5 ohm ground system, independent of traction power grid to prevent damaging voltage fluctuations and noise coupled to sensitivity communications system equipment, shall be provided for each optical network node or radio communications shelter. Where a ground resistance 5 ohms or less is not possible without the use of chemical ground electrodes, then such chemical ground electrodes should be installed in order to provide sufficient low-impedance ground in locations of high soil resistivity.

Contractors should perform all necessary calculations and soil condition determinations to design ground rod depths, quantities, and lengths

Insulated No. 4/0 AWG wire with green insulation should be used for connecting ground grid to Telecommunications Grounding Bus-bars at cabinets.

A halo type grounding ring should be used in all communications rooms and structures attached to towers and antennas. Bonding should be accomplished between these structures and the halo ground in the perimeter of the interior walls of the nearby communication structures in accordance with the latest revision of the applicable standards, codes and guidelines.

3.4.2 Applicable Standards for Communication Equipment Grounding

The following standards, codes and guidelines are to be complied with when designing and implementing the grounding of communications equipment including but not necessarily limited to:

Institute of Electrical & Electronics Engineers (IEEE) 1100: "Recommended Practice for Power Grounding Sensitive Electronic Equipment."

Institute of Electrical & Electronics Engineers (IEEE) C62.41-2000: “IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits”.

ANSI-J-STD-607-A “Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications.”

Institute of Electrical and Electronics Engineers (IEEE) 80: “Guide for Safety in AC Substation Grounding”.

Institute of Electrical & Electronics Engineers (IEEE) 81: “Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System”.

4.0 SUMMARY AND RECOMMENDATIONS

Cross bonding of impedance bonds attached to the various track and grounding of signals will follow the practice of Amtrak on their 25 kV, 60 Hz electrification in order to maintain the integrity of broken rail detection. Bonding between rails and grounding as shown herein will provide for touch and step potentials that meet recognized safety standards.

Communications grounding shall be in accordance with manufacturers' recommendations and in accordance with applicable IEEE and ANSI standards.

5.0 SOURCE INFORMATION AND REFERENCES

- BS EN 50122-1:1998 specifying maximum permissible touch/accessible voltages during fault conditions
- The Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA)
- Amtrak Electrified Territory Instructions for Cross-Bonding and Structure Grounding and Related Instructions dated February 15, 1991
- Institute of Electrical & Electronics Engineers (IEEE) 1100: “Recommended Practice for Power Grounding Sensitive Electronic Equipment.”
- IEEE C62.41-2000: “IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits”.
- ANSI-J-STD-607-A “Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications.”
- Institute of Electrical and Electronics Engineers (IEEE) 80: “Guide for Safety in AC Substation Grounding”.
- Institute of Electrical & Electronics Engineers (IEEE) 81: “Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System”.
- IEEE 81: “Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System”.

6.0 DESIGN MANUAL CRITERIA

6.1 INFORMATION FOR INCLUSION IN DESIGN MANUAL

The following sections address the different requirements for bonding and grounding of the train control and communications subsystems and highlight areas where bonding and grounding requirements for the traction power and OCS subsystems may conflict.

Consideration of the TCC subsystem requirements has been based upon the requirements of Amtrak's Electrified Territory Instructions For Cross-Bonding And Structure Grounding And Related Instructions For Electric Traction Employees Grounding OCS And For C&S Employees Maintaining Track Circuits

6.2 GENERAL

The requirements given in TM 3.2.6 TES Requirements for Grounding and Bonding and Protection from Electric Shock shall be followed, except as described herein.

6.2.1 Definition of Terms

Technical terms, acronyms, foreign phrases/terms, etc. and or terminology that may have specific connotations with regard to the California High-Speed Train System are shown in TM 0.0a. Terms used herein that may not be included in TM 0.0a are shown below.

Automatic Train Control (ATC):	The collective name for the train control subsystems that typically comprise the Automatic Train Protection, the Automatic Train Operation, and Automatic Train Supervision sets of functions that govern train operations on the main tracks.
Drain Bond	An impedance bond connecting the rails to a substation return or a safety ground where no insulated joints exist.
Fiber Optic Cable System	A data transmission technology that relies on light rather than electricity, conveying data through a cable consisting of a central glass core surrounded by layer of plastic.
GSM-R	The radio version of the Global System for Mobile Communications (originally from Groupe Spécial Mobile) used on railroads for control systems in Europe and possibly to be adapted for CHST.
Impedance bond	An electrical device located between the rails consisting of a coil with a center tap used to bridge insulated joints in order to prevent track circuit energy from bypassing the insulated joint while allowing the traction return current to bypass the insulated joint. The center tap can also be used to provide a connection from the rails to the static wire and/or traction power facilities for the traction return current.
Insulated Joint	A joint in the running rail used to prevent track circuit energy on one side of the joint from flowing to the other side of the joint.
Main Line	The tracks allocated to the high speed train traffic at normal commercial speed and not normally used for switching or storage. Main Line tracks always have track circuits.
Neutral Leads	The wires connecting the center tap of impedance bonds to other impedance bonds and/or to traction power ground circuits.

Passing Track	Track connected to the Main Line on both ends and allowing for stopping trains for commercial reasons, such as at stations, for operating purposes such as overtaking trains. For regulatory and signaling purposes the passing track is treated the same as Main Line track.
Rail Return	The combination of track structure, jumpers, impedance bonds, grounds, static wire, and cables that provide an electrical return path from a train to a substation or other traction power facility such as a switching station or paralleling station.
Track Circuit	A method of determining occupancy of a section of track and/or a broken rail by sending an electrical signal down the track from the transmit to the received end of the section of track and indicating that the section of track is complete and not occupied by detecting a minimum level of the proper signal as the receive end.
Transition Track	A section of track used for the transition of trains between the main lines and Yard tracks. Transfer Tracks are equipped with both the main line ATC System and Yard Signal System and always have track circuits.
Vital	A designation placed on a system, subsystem, element, component or function denoting that satisfactory operation of such is mandatory for safety.
Wayside Signals	Devices located along the right-of-way for providing information to the locomotive engineers relative to train operations as opposed to the cab signal displays that are located within the control compartment of the rolling stock.
Yard Signal System	The train control system that controls safe movements within the limit of Yard Tracks.
Yard Track	A section of track used for storage of trains that is auxiliary to the main track and nut used by trains that are carrying passengers. Refuge tracks at stations are yard tracks. Yards consist of more than one yard track used for storing trains, inspecting trains, and accessing maintenance facilities. Yard tracks may or may not have track circuits on them.

Acronyms

ac	Alternating Current
ATC	Automatic Train Control
BS	British Standard (The English Language version of the EN Standard)
CFR	Code of Federal Regulations
EC	European Community
EMC	Electromagnetic Compatibility
EN	European Norm (Standard in the EC)
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
FCC	Federal Communications Commission
FRA	Federal Railroad Administration
GSM-R	Global System for Mobile Communications - Rail
NIST	National Institute of Standards and Technology
OCC	Operations Control Center

PA	Public Address
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
TCC	Train Control and Communications
TCP/IP	Transmission Control Protocol/Internet Protocol
TCR	Transmission Communications Room
UPS	Uninterruptible Power Supply

6.3 CROSS-BONDING

Directive Drawings (DD) TM 3.3.4 A through D illustrate the impedance bonding requirements as described in the following sections.

6.3.1 Definition of types of impedance bond connections (DD TM 3.3.4 – A)

An "**A**" point is defined as a location where impedance bond neutral leads on all tracks are bonded together, to OCS support structures which are in turn bonded to the static return wires and, at traction power facilities such as substations, switching stations, and paralleling stations, directly to the traction power facility return bus.

A drain bond is an impedance bond installed in order to connect the rails to traction power facilities such as substations, switching stations, and paralleling stations where no insulated joints exist in the vicinity of the traction power facility. At such locations the neutral leads of the drain bonds shall be connected directly to the traction power facility return bus.

A "**C**" point is defined as a location with impedance bonds to bypass insulated joints on one track but with no cross-bonding.

6.3.2 Distance between types of impedance bond connections (DD TM 3.3.4 – B)

Cross-bond locations ("A" points) shall include a minimum of two (2) track circuits between them and should, if practical, be located not less than 6,000 feet nor more than 12,000 feet apart.

6.3.2.1 For cross-bond locations over 6,000 feet apart:

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

6.3.2.1 For cross-bond locations less than 6,000 feet apart:

- There shall be a minimum of three (3) track circuits between the cross-bond locations ("A" points).
- Distance between cross-bond locations shall be not less than 250% of the length of the longest track circuit, any portion of which lies between the cross-bond points.
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- In no case will a distance of less than 3,000 feet between cross-bond locations ("A" points) be permitted.

The "percent ratio" (minimum of 167% in 3.3.2.1 and minimum of 250% in 3.3.2.2) is calculated for any given section between cross-bond locations ("A points) as D(XB) divided by D(LTC), where D(XB) is the distance between cross-bond points defining the section and D(LTC) is the length of the longest track circuit in the section.

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

6.3.3 Cross-bonding at interlockings (DD TM 3.3.4 – C)

Cross-bonding shall be placed as close to interlocking crossovers as possible to reduce the possibility of flashover of-insulated joints in crossovers. If possible, an "A" point shall be placed at one of the interlocking home signal locations at each interlocking. This shall be done consistent with the Rules in 3.3.2 and the need to place an "A" point at each substation, switching station or paralleling station return bus location.

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

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

6.3.4 Cross-bonding in single bore tunnels

Where an “A” point is required within a single bore tunnel the neutral leads of the impedance bonds will be connected to the static return conductor in that bore.

6.3.5 Signals (DD TM 3.3.4 – D)

The base of a ground-mounted signal mast is to be bonded to the traction return system by direct connection to the neutral leads at the insulated joints adjacent to the signal. There are to be no other electrical connections between the signal mast and other structures or other rails or neutral leads unless specifically called for on the plan as part of an "A” point.

Signal bridges or cantilever structures at a location that is not an "A" point shall not be electrically connected to any neutral leads or any portion of any track structure that is part of the signal system. These structures shall be aerially connected to the nearest structure that is bonded into the static wire return system, preferably at both ends of any bridge spanning multiple tracks.

6.3.6 Signal Cables

Signal control or lighting cables and switch cables in electrified territory shall not have metallic shielding. Metallic messenger or duct shall not be used in any way that could cause an electrical interconnection between signals or signal bridges and signal instrument housings.

6.4 COMMUNICATIONS

The purpose of this section is to enable the planning, design, and installation of data communications grounding and bonding systems within a building with or without prior knowledge of the data communications systems that will subsequently be installed. This section also provides recommendations for grounding and bonding of towers and antennas and supports a multivendor, multiproduct environment as well as various system installation practices.

The following equipment requires special attention to proper grounding:

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- CCTV cameras, VMS signs and other field equipment subject to EMI from train and traction power operations

6.4.1 Electrical Considerations for the Grounding of Communications Equipment

All grounding shall be in accordance with applicable standards, as listed in section 3.4.2, and local codes except as modified herein. Each piece of equipment shall also be grounded in accordance with the recommendations of the manufacturer.

The communications ground shall be independent of the traction power ground to prevent damaging voltage fluctuations and noise coupled to sensitivity communications system equipment.

A 5 ohm ground system, independent of traction power grid to prevent damaging voltage fluctuations and noise coupled to sensitivity communications system equipment, shall be provided for each optical network node or radio communications shelter. Where a ground resistance 5 ohms or less is not possible without the use of chemical ground electrodes, then such chemical ground electrodes shall be installed in order to provide sufficient low-impedance ground in locations of high soil resistivity.

Contractor shall perform all necessary calculations and soil condition determinations to design ground rod depths, quantities, and lengths

Insulated No. 4/0 AWG wire with green insulation shall be used for connecting ground grid to Telecommunications Grounding Bus-bars at cabinets.

Halo ring grounding ring shall be used in all communications rooms and structures attached to towers and antennas. Bonding shall be accomplished between these structures and the halo ground in the perimeter of the interior walls of the nearby communication structures. in accordance with the latest revision of the applicable standards, codes and guidelines.

6.4.2 Applicable Standards for Communication Equipment Grounding

The following standards are to be in force when designing and implementing the grounding of communications equipment including but not necessarily limited to:

Institute of Electrical & Electronics Engineers (IEEE) 1100: “Recommended Practice for Power Grounding Sensitive Electronic Equipment.”

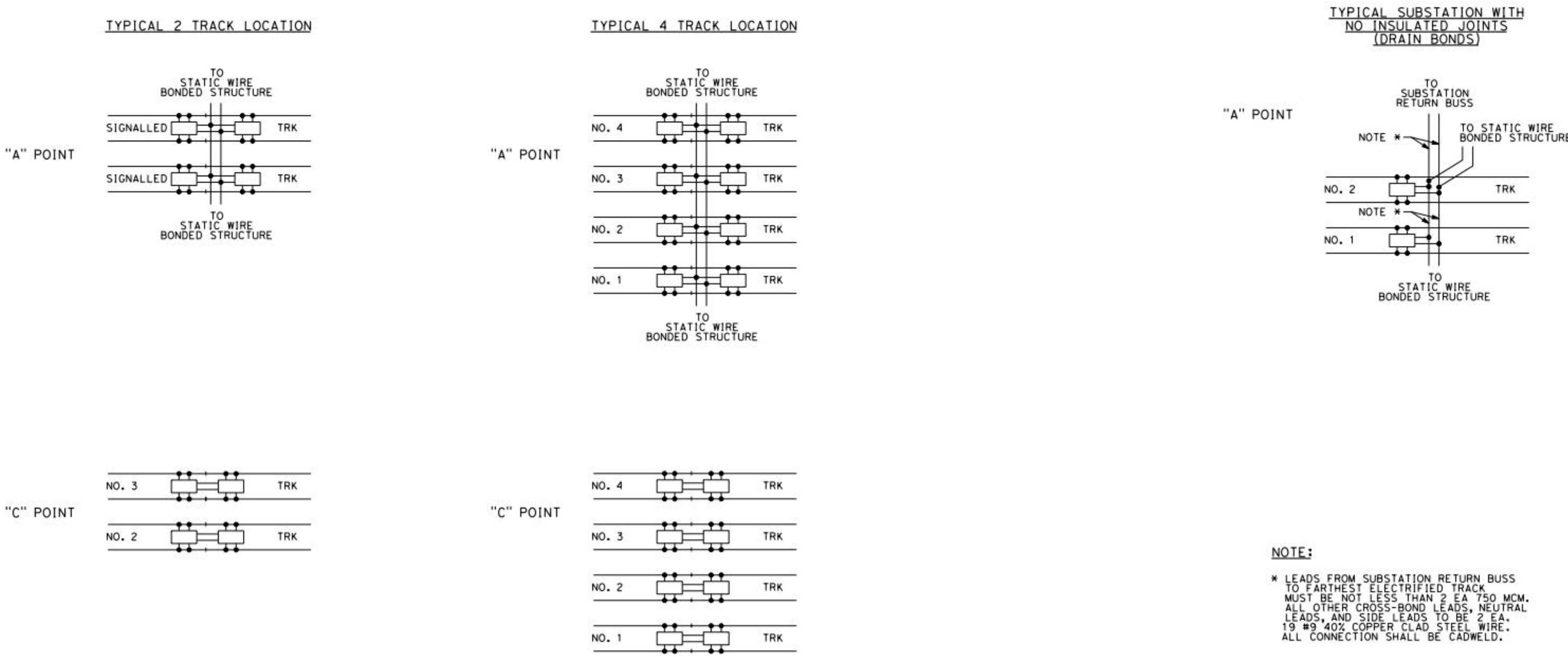
Institute of Electrical & Electronics Engineers (IEEE) C62.41-2000: “IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits”.

ANSI-J-STD-607-A “Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications.”

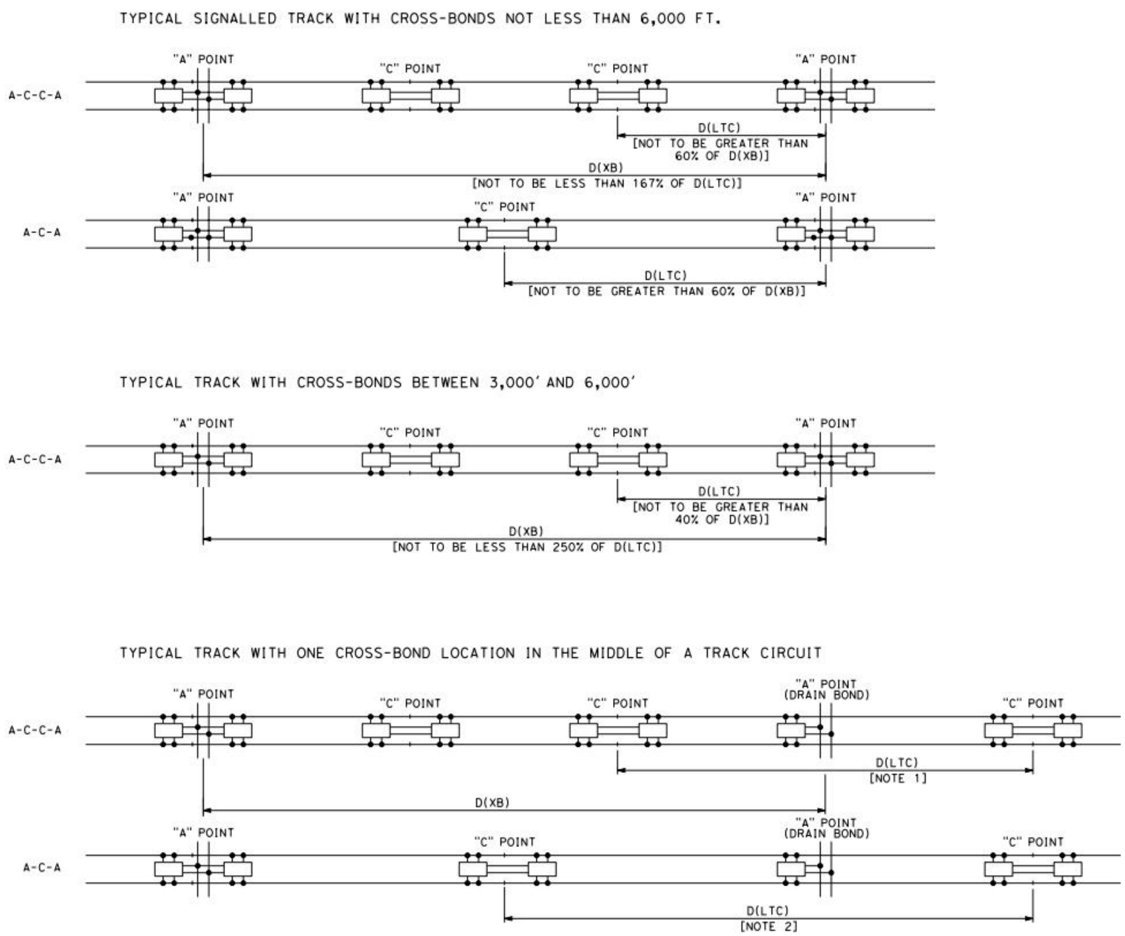
IEEE 80: “Guide for Safety in AC Substation Grounding”.

IEEE 81: “Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System”.

APPENDICES



ATC GROUNDING AND BONDING "A" & "C" POINTS AND DRAIN BOND LOCATIONS – FIGURE TM 3.3.4 –A



D(LTC)* LENGTH OF LONGEST TRACK CIRCUIT. ANY PORTION OF WHICH LAYS BETWEEN "A" POINT LOCATIONS.

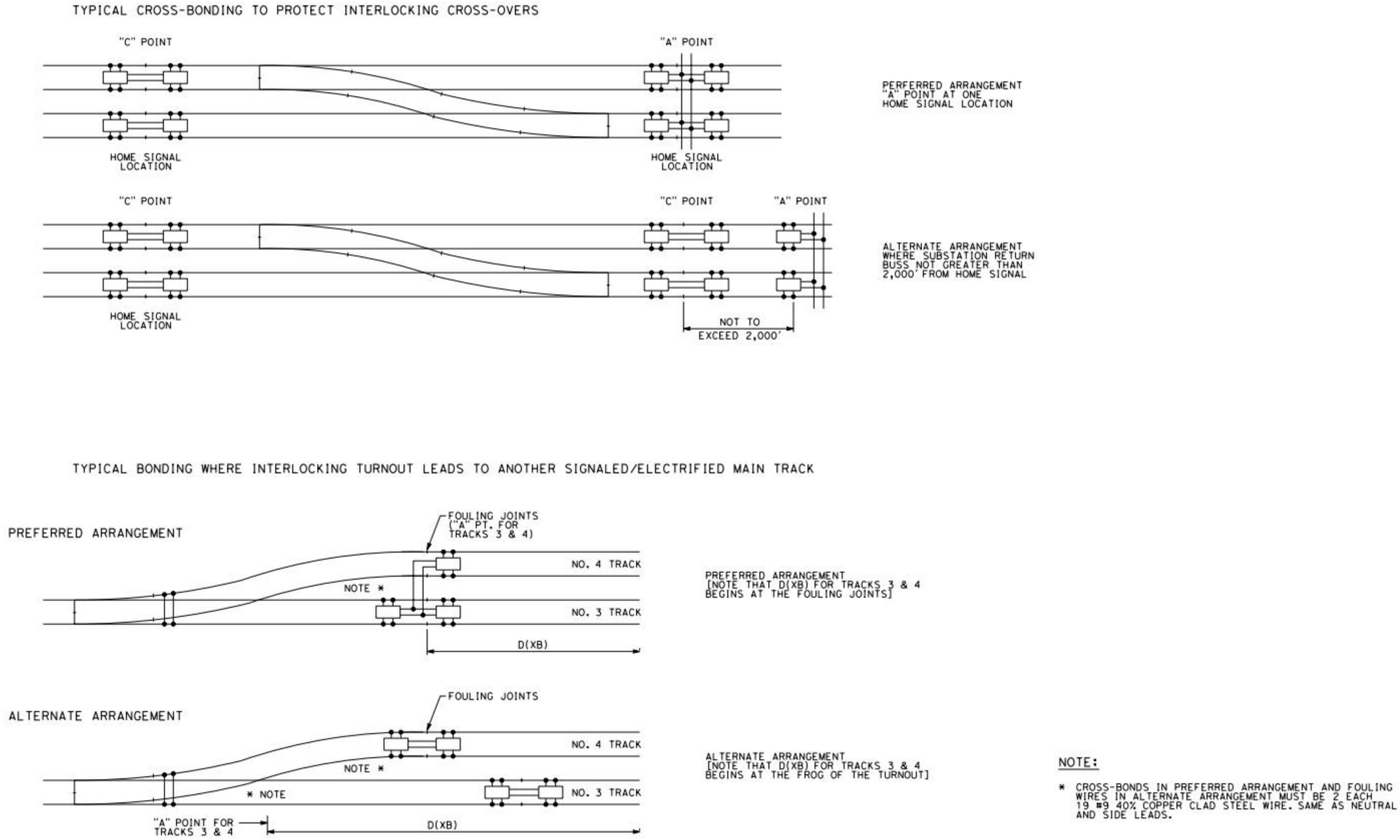
D(XB)* DISTANCE BETWEEN "A" POINT LOCATIONS.

NOTES:

1. D(LTC) NOT TO BE GREATER THAN 60% OF D (XB) IF D(XB) IS 6,000 FT. OR GREATER.
D(LTC) NOT TO BE GREATER THAN 40% OF D (XB) IF D(XB) IS LESS THAN 6,000 FT.

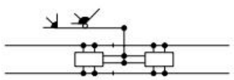
2. D(LTC) NOT TO BE GREATER THAN 60% OF D(XB) AND D(XB) IS TO BE AT LEAST 6,000 FT.

ATC GROUNDING AND BONDING CROSS-BONDING PRACTICE – FIGURE TM 3.3.4 - B



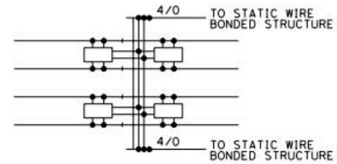
ATC GROUNDING AND BONDING CROSS-BONDING AT INTERLOCKINGS – FIGURE TM 3.3.4 – C

GROUND MOUNTED SIGNAL MAST



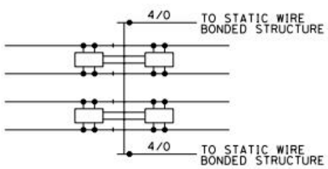
CADWELD CONNECTION [1 EA 19 #9 40% COPPER CLAD STEEL WIRE] FROM BASE OF SIGNAL MAST TO NEUTRAL LEADS OF INSULATED JOINTS ON TRACK GOVERNED BY SIGNAL ONLY. NO OTHER CONNECTION TO OTHER TRACKS. STRUCTURES OR SIGNALS UNLESS PART OF "A" POINT SHOWN ON PLAN

SIGNAL BRIDGE, PART OF AN "A" POINT LOCATION



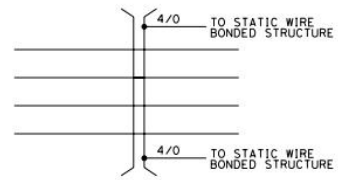
AERIAL CONNECTION FROM EACH END OF SIGNAL BRIDGE TO NEAREST STATIC WIRE BONDED STRUCTURE. AERIAL CONNECTIONS NOT REQUIRED IF SIGNAL BRIDGE IS PART OF TRANSMISSION STRUCTURE BONDED INTO STATIC WIRE RETURN SYSTEM.

SIGNAL BRIDGE, NOT AT AN "A" POINT LOCATION



AERIAL CONNECTION FROM EACH END OF SIGNAL BRIDGE TO NEAREST STATIC WIRE BONDED STRUCTURE. NO CONNECTIONS TO ANY PART OF TRACK OR NEUTRAL LEADS.

OVERHEAD BRIDGE



AERIAL CONNECTIONS FROM EACH END OF OVERHEAD BRIDGE TO NEAREST STATIC WIRE BONDED STRUCTURE.

ATC GROUNDING AND BONDING OF SIGNALS AND OVERHEAD STRUCTURES – FIGURE TM 3.3.4 - D