American Railway Engineering and Maintenance of Way Association
Letter Ballot

1. **Committee and Subcommittee: Committee 33 – Electrical Energy Utilization, no subcommittee**
2. **Letter Ballot Number: 19-33-01**
3. **Assignment: 33-02**
4. **Ballot Item: Revise Part 2 – Clearances**
5. **Rationale: General updates**

AREMA

American Railway Engineering and Maintenance-of-Way Association

Part 2

Clearances

--- ~~2010~~2020 ---

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Note: In general, converted Metric values in the Tables and throughout this Part have been rounded up to the next higher increment of 5 mm, except for instances where specific mathematical calculations have been performed.

SECTION 2.0 CHANGES FROM 1995, ~~&~~ 2005 & 2010 EDITIONS (~~2010~~2020)

2.0.1 GENERAL (~~2010~~2020)

a. The two diagrams; Typical Over-Running Third Rail Arrangement (Figure 33-2-1) and Typical Under-Running Third Rail Arrangement (Figure 33-2-2) were added in 2010.~~; were previously presented as Figure 33-2-2A after that diagram was moved into Chapter 33 from Chapter 12, where clearance outlines were depicted in Figure 33-12-1 Third-rail Territory.~~ As discussed below, it is not practical to present a single clearance diagram that would be applicable to either existing or new properties, since there are too many variable dimensions. Therefore, these diagrams ~~have been redrawn and updated to present~~represent typical modern installations.

~~Part 2 has been generally updated, including most of the tables and Figures 33-2-1 and 33-2-2 (which are now numbered 33-2-3 and 33-2-4), to more comprehensively reflect conditions and clearances that are appropriate for mass transit and light rail systems, as well as for railroad applications. Figure 33-2-5 Clearance Requirements for Energized Ancillary Conductors has been added.~~

b. The original clearance drawings, along with the Report of the Engineering Division on Electrical Facilities (AREA Committee on Electrical Energy Utilization) for clearances under structures on lines that are or may be electrified ~~was declared~~were adopted by the AAR Engineering Division on December 12, 1975. ~~With the exception of altitude compensation, the proposed clearance diagram was written into the Federal-Aid Highway Program Manual on May 10, 1976 for planned construction or reconstruction of railroad overpass structures.~~ Using a simplified approach for railroads contemplating electrification, 23 CFR Chapter 1, Part 646, Subpart B, Appendix to Subpart B, which implements the provisions of 23 CFR 646.212(a)(3), states: “For 25 kV lines, a vertical clearance of 7.4 meters (24’- 3”) may be approved. For 50 kV lines, a vertical clearance of 8.0 meters (26’- 3”) may be approved.”

c. Updated clearance values, figures and tables ~~for inclusion in Chapter 33~~ were ~~declared~~ adopted by AREA in March 1995. ~~However, c~~Consequent upon ~~recent~~ operating experience on the New Haven – Boston segment of the Amtrak Northeast Corridor, which was energized at 25 kV based on the 1995 values, the recommended electrical clearances ~~given in Table 33-2-2 for 25 kV and 50 kV systems have been~~were increased in 2010 to match the values ~~that were~~ originally adopted in 1975. The clearances shown in Table 33-2-2 of this section, as modified by Table 33-2-3, should be achieved under calculated worst case environmental conditions.

~~d. The additional materials, contained in Section 2.2.12 Technical Notes (1995), have been incorporated into the relevant sections.~~

~~e.~~d. Part 2 of Chapter 33 deals primarily with the additional clearances required to accommodate electrification. For general clearance requirements, refer to Chapter 28 Clearances.

~~**NOTE: It must be recognized that the requirements for total vertical clearance and total lateral clearance to accommodate electrification will vary dependent upon the selected operating voltage, vehicle and pantograph size, and track conditions, including track curvature and super-elevation, and that these clearance requirements differ for dynamic passing situations and stationary static situations. The guidelines contained in Part 2 provide the means to identify all of the relevant allowances, which must be considered in determining the required clearances, but do not direct the user to a particular conclusion, since design decisions can only be made with a full understanding of the actual circumstances involved. The calculated values, shown in this Part, are provided as Examples of how Clearances should be determined, but should not be assumed to represent engineered recommendations.**~~

SECTION 2.1 THIRD-RAIL ARRANGEMENTS (~~2010~~2020)

2.1.1 GENERAL (~~2010~~2020)

a. Many of the existing railroad and transit properties use different approaches to positioning the third rail which, in many instances, have been dictated by historical issues, such as car width, track gauge, tunnel clearances, truck design (particularly for mounting of the collector shoes), and over-running or under-running current collection, so it is ~~difficult, if not impossible,~~not practical to establish a recommended standard clearance arrangement. These issues may also influence design decisions for new systems.

b. In addition, different properties have adopted varying approaches to the measurement of "gauge" to the third rail from the running rail. Some measure from running edge to the inside edge of the third rail, which is a logical and easy measurement to take in the field, whereas others measure from running edge to the center line of the third rail, which is much more difficult to establish accurately and is not recommended.

c. Once installed, the third rail is essentially in a fixed position and is not subject to the same degree of wear as the running rail, which suffers from both gauge and~~or~~ head wear, plus~~and the~~ vehicle wear, since truck wheels experience both flange and tread wear. These wear characteristics effectively mean that the truck and the collector shoe can move closer to or further away from the third rail, particularly on curves. Similar issues also occur with track gauge widening. Third rail "gauge" is, therefore, an issue for both track maintenance and vehicle maintenance.

d. Wheel tread wear should be addressed during vehicle maintenance by adjusting the shoe pivot point as the tread wears.

e. Lack of attention to these maintenance issues can lead to such problems as parts of the truck or collector shoe hitting the cover board, resulting in damage to both the shoe and the cover board.

f. The Third Rail Diagrams depict two typical installations: Figure 33-2-1 shows a Typical Over-Running Shoe arrangement and Figure 33-2-2 a Typical Under-Running Shoe arrangement.

g. Specific recommendations are not made for clearance dimensions. However, where the third rail is to be constructed in polluted areas, such as in close proximity to the sea or heavy industrial plants, electrical clearance allowances and other relevant factors should be investigated. In addition, for Third Rail systems installed above an elevation of 3,000-feet (~~914~~900 m), the altitude compensation factors shown in Table 33-2-3 should be considered.

2.1.2 DESIGN, CONSTRUCTION AND MAINTENANCE ISSUES (2010)R(2020)

a. Designs for Third Rail systems must recognize that various transit agency or railroad departments will be responsible for different aspects of the long term maintenance and operation of the system and the interface issues associated with third rail clearances must be addressed and clearly understood by all parties.

For Diagram, refer to Separate Attachment.

Figure 33-2-1. Typical Over-Running Third Rail Arrangement

For Diagram, refer to Separate Attachment.

Figure 33-2-2. Typical Under-Running Third Rail Arrangement

b. Design criteria should address the differences between construction and maintenance tolerances. Installation tolerances for new or replacement work should have smaller values than those to be permitted for maintenance, but both sets of tolerances relate to the initial Design Location. The "as-built" position can lie anywhere within the Construction Tolerance limits of the Design Location. However, it should be noted that Construction Tolerances should NOT be based on the "as-built" position, but must be related to the original intended Design Location.

c. Design criteria should identify the lateral and vertical offsets of the third rail from the adjacent running rail, together with both construction and maintenance tolerances.

d. Design criteria should define the minimum track radius below which pre-curved rail must be installed to permit satisfactory current collection in curved track areas.

e. Design criteria should address the spacing of expansion gaps in both tangent and curved track.

f. Design criteria should address the spacing on the vehicles between the third rail collector shoes in relation to the length of sectionalizing gaps in the contact rail, and the length of other construction gaps that are required at track turnouts, interlockings, stations, yards and terminals, and, on systems where grade crossings are permitted, the maximum width of the required grade crossing gap to ensure that vehicles cannot become stranded due to lack of a power source. This may require the early establishment of the minimum permissible number of cars in a train consist, since it is often difficult to eliminate all long third rail gaps in special track work areas, particularly in yards, due to the lack of space.

g. Design criteria should identify the anchoring intervals for the third rail to prevent movement of the center of the third rails section that could be induced by the passage of the collector shoe. The effects of thermal expansion of the third rail must also be accounted for, particularly on tight curves or on steep gradients, where the third rail may not slide easily through the insulated support brackets.

h. Design criteria should address material make-up of both the collector shoe and the third rail, and associated compatibility issues.

i. Clearance values to the Third Rail are affected by:
   - Track Maintenance.
   - Rolling Stock Maintenance.
   - Third Rail Wear.

j. In automated systems, the antennae for train control in automatic train operation (ATO) and station stopping are often truck-mounted. If these antennae are positioned such that they are in close proximity to the Third Rail, the antennae may need to be adjusted periodically to accommodate both wheel tread and wheel flange wear.

k. The clearance offset to fixed permanent way structures will generally be dictated by vehicle clearance requirements but, in third rail territory, the minimum clearance envelope must include additional clearance allowances in the vicinity of the third rail to ensure permanent way structures cannot intrude.

l. The clearances must also include the distance from the edge of the shoe on the non-third rail side to any obstruction, particularly in round tunnels where this shoe will be lower than the one on the third rail side and thus much closer to the tunnel wall.

SECTION 2.2 RECOMMENDED CLEARANCE CRITERIA~~SPECIFICATIONS~~ TO PROVIDE FOR OVERHEAD ELECTRIFICATION (~~2010~~2020)

NOTE: It must be recognized that the requirements for total vertical clearance and total lateral clearance will vary dependent upon the selected operating voltage, vehicle and pantograph size, and track conditions, including track curvature and super-elevation, and that these clearance requirements differ for dynamic passing situations and stationary static situations. These guidelines provide the means to identify all of the relevant allowances, which must be considered in determining the required clearances, but do not direct the user to a particular conclusion, since design decisions can only be made with a full understanding of the actual circumstances involved.

2.2.1 GENERAL (~~2010~~2020)

a. In general, all of the equations and sample calculations contained in Part 2 assume vehicle operations over tangent track, and have excluded the effects of side winds, ice loading and OCS vibrations caused by vehicle operations. These items and allowances for operations over curved track, where applicable, should be taken into account on a site specific basis during the detailed engineering analyses and design of a project.

b. The figures and tables in this Part include the electrical clearances recommended for direct-current (dc) system voltages of 750 V, 1500 V and 3000 V, and alternating-current (ac) system voltages of 12.5 kV, 25 kV and 50 kV for pantograph heights above top of rail between 12 feet (3.65m) and 25 feet (7.62m).

c. The electrical clearances for dc voltages of 750 V, 1500 V and 3000 V are based upon existing good practice and construction limits.

d. The electrical clearances for high-voltage ac overhead contact systems are based primarily on those railroads already electrified at 12.5 kV and 25 kV. The clearances for 50 kV are approximately twice the proven and accepted clearance requirements for 25 kV.

e. While some existing systems remain at 25 Hz, t~~T~~he recommended standard power supply for high-voltage ac overhead electrification in North America is single phase at a frequency of 60 Hz.

f. Voltages given are nominal system operating voltages; calculated clearances contain allowances for a~~±~~ 20% increase over~~variation of~~ the nominal voltage due to voltage fluctuation. It is assumed that suitable lightning protection apparatus is made an integral part of the installed system.

g. The figures, tables and basic formulae are included to facilitate calculation of vertical and lateral openings for the various dc and ac voltages. The engineer should consider site specific conditions that may result in deviations from the values quoted in this Part.

h. For calculation purposes, electrical clearances should be based on the selected system voltage, as specified, with clearances being maximized for operational needs. In new construction, these clearances should be based on the "normal~~ minimum~~" values as shown in Table 33-2-2. The designated normal clearances shall be adopted at all locations, wherever practicable.~~For existing overhead structures, where physical constraints exist and normal clearances are not achievable, even with considerable expense, the recommended absolute minimum clearances, shown in Table 33-2-2, may be considered.~~

i. For existing overhead structures, where it can be demonstrated that it is not practicable to provide normal clearances, adoption of the minimum clearances shown in Table 33-2-2 may be considered. However, prior to their adoption, the following factors require further evaluation and should be assessed on a site specific basis:

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

Adoption of the ~~absolute~~ minimum clearances may require the use of protective shields, insulated messenger wires/insulated feeders, or other special measures in order to assure system reliability and maintainability under potentially adverse conditions~~. These requirements should be assessed on a site specific basis.~~

~~i. Minimum vertical clearances generally assume the use of contact-wire-only construction with closely spaced supports. If messenger-contact wire catenary construction is used, the vertical opening must be increased by the messenger to contact wire spacing, plus an additional uplift allowance where extended length OCS spans are used.~~

j. No recommendations are made as to standard or normal contact wire heights or clearances, since these will be governed by operating conditions and requirements. Where personnel are permitted or required to go on top of rolling stock, appropriate safety clearances should be established and contact wire height requirements must be greater than where such practice is prohibited. Where sufficient additional clearance cannot be provided, safety equipment should be incorporated that will prevent personnel access when the OCS is energized.

2.2.2 DESIGN AND CONSTRUCTION CLEARANCE (~~2010~~2020)

A design and construction clearance, as opposed to an electrical clearance, must include provision for a number of factors, the most important of which are:

- ~~T~~the electrical clearance between the structure and live parts of the OCS.
- ~~S~~system height of the OCS including contact wire, messenger wire and hardware.
- ~~T~~the dynamic movement or displacement of the pantograph in the vertical and horizontal directions, and the uplift of the OCS when the contact wire is swept by the pantograph.
- ~~T~~the electrical clearances between the contact wire and vehicle load gauge.
- ~~T~~the dynamic movement or displacement of the rolling stock in the vertical and horizontal directions.
- ~~T~~the vehicle load gauge.
- ~~C~~civil and mechanical engineering tolerances in construction and for maintenance of the track and OCS.

- ~~R~~required safety clearances for access to areas in proximity to energized parts.

2.2.3 VERTICAL CLEARANCE (~~2010~~2020)

The vertical clearance required to accommodate the OCS at overpasses and through-truss bridges or in tunnels can be broken down into three specific components:

- Electrical clearances and OCS requirements (H dimension ~~in the figures~~) Figure 33-2-3.
- ~~l~~Load gauge (Y dimension ~~in the figures~~) Figure 33-2-3 and 33-2-4.
- Ttrack construction requirements, including future track maintenance allowances (T_3 dimension ~~in the figures~~) Figure 33-2-3.

2.2.3.1 Clearance Requirements for the OCS (H) (2020)

Clearance requirements for the OCS comprise the depth of the OCS equipment at the supports and/or in-span between supports including allowances for changes in sag due to climatic conditions, plus electrical clearances from the energized components to the grounded structure or the grounded vehicle body under both static and dynamic conditions. These dimensions and clearances are discussed in the following sections.

2.2.3.2 Load Gauge (Y) (2010)R(2020)

a. The load gauge or vehicle height is shown as the "Y" dimension on the clearance diagrams.

b. For LRT systems, vehicle equipment heights typically range from 10'-0" to 12'-0" (3.05 to 3.65 m). For LRT systems, the designer should reference the designated vehicle clearance diagrams.

c. The normal load gauge height for most major railroads will vary between 15'-6" (4.72 m) Plate "C" and 20'-3" (6.17 m) Plate "H". Additional information is included in Chapter 28, Clearances for railroad systems.

d. For railroads, oversize loads may be as great as 25 feet (7.62 m) but these will be the exception rather than the rule. Abnormal load heights, which do not allow for the minimum electrical clearance to contact wires, may be accommodated by de-energizing the OCS providing sufficient mechanical clearance exists.

2.2.3.3 Track Construction and Maintenance Requirements (T_3) (2010)R(2020)

Traditionally, a 12-inch (305 mm) allowance has been included in main line railroad OCS design to allow for future lifting or ballasting of track, installing rail with a higher cross section and/or for construction/maintenance tolerances for the civil works, except where use of a smaller allowance is required by local circumstances, such as at passenger stations, overpasses, tunnels, and grade crossings. A similar allowance should also be considered for commuter rail, rapid transit and LRT systems, although the total amount may be smaller, due to the typically greater frequency of passenger stations and grade crossings.

2.2.4 TOLERANCES IN THE OCS SYSTEM AND POSITION OF TRACK (~~2010~~2020)

a. Allowances should be made for civil engineering and wire installation and maintenance irregularities in determining the vertical and lateral structure openings.

b. Under ~~absolute~~ minimum clearance conditions, the OCS should be maintained to ±0.5 inch (13 mm) of the design level at the supports for non-high speed railway and transit application. Under normal ~~minimum~~ clearance conditions, the OCS should be maintained to ±1 inch (25 mm) of the design level at supports.

~~b.~~c. For high speed rail applications, the OCS should be maintained to provide level contact wire current collection with allowable contact loss values of 1-2% maximum.

d. For railroads, the position of the track is assumed to be maintained, as a minimum, within the tolerances mandated by the FRA Track Safety Standards. However, where those requirements or the railroad maintenance of way standards are not more restrictive, the track should be maintained within the following tolerances of the design position, particularly at structures with limited lateral or vertical clearances, as shown by the T_3 dimension in Figure 33-2-3 and by the L dimension in Figure 33-2-4.

Table 33-2-1. Track Tolerances for Non-High Speed Applications

Clearance Condition	Dimension
Track vertical alignment at normal ~~minimum~~ clearance locations	+ 1.0 inch / - 0.5 inch (+ 25 mm / - 13 mm)
Track vertical alignment at ~~absolute~~ minimum clearance locations, such as tunnels, bridges and overpasses	± 0.5 inch (± 13 mm)
Track lateral alignment at normal ~~minimum~~ clearance locations	± 1.0 inch (± 25 mm)
Track lateral alignment at ~~absolute~~ minimum clearance locations, such as tunnels, bridges and overpasses	± 0.5 inch (± 13 mm)

2.2.5 ELECTRICAL CLEARANCES FROM ENERGIZED PARTS TO GROUNDED PARTS (AIR CLEARANCES) (~~2010~~2020)

a. The Clearance diagrams, Figure 33-2-3 and Figure 33-2-4, recognize two types of electrical or air clearances, "Static" and "Passing", designated as C_A and P_A in Table 33-2-2. These clearances are used in the two basic formulae to calculate vertical and horizontal structure openings in conjunction with Table 33-2-7 and Table 33-2-8. Typical electrical clearances are given in Table 33-2-2 and typical vertical clearances above static load height are given in Table 33-2-9. For an OCS installed above an elevation of 3,000-feet (~~914~~900 m), the altitude compensation factors discussed in section 2.2.7 and ~~shown in~~ Table 33-2-3 should~~must~~ be considered~~used~~.

b. The Passing Electrical Clearance, designated P_A, is the distance between the OCS messenger wire, contact wire~~s~~, pantograph, or other live parts of either the vehicle or OCS and the grounded vehicle load gauge, overhead structure or other adjacent fixed structure under dynamic operating conditions, such as during the short time it takes a train to pass or in adverse climatic conditions when the conductors are not stationary.

c. The Static Electrical Clearance, designated C_A, refers to the distance between the live parts of a vehicle or the OCS, whether or not it is subjected to pantograph pressure, and the grounded parts of a vehicle or adjacent fixed structure while the vehicle is stationary.

d. In some instances the sum of the dynamic allowances and the passing electrical clearance may be greater than the static electrical clearance. For these cases, the larger value should be used. This approach should be applied to the design of the OCS and maximum car profile (including any load) in stations, terminals and yards, or wherever vehicles may remain stationary for extended periods.

e. Where the OCS is to be constructed in polluted areas, such as in close proximity to the sea or heavy industrial plants, an additional clearance allowance, as shown in Table 33-2-2, should be added to both the Static and Passing Clearance OCS values and to the Ancillary Conductor Clearance values.

f. For Clearances from Energized Ancillary Conductors refer to Article 2.2.6 and Figure 33-2-5 of this Part.

Insert Figure

Figure 33-2-3. Vertical Clearance Allowances at Overbridges and Tunnels

Insert Figure

Figure 33-2-4. Vertical and Lateral Clearances at Overbridges (Tunnels require detailed analysis)

Table 33-2-2. Electrical (Air) Clearances from Energized Parts of the OCS or Vehicle to Grounded Structures or Grounded Parts of the Vehicle and from Ancillary Conductors to Grounded Structures

Nominal System Voltage	Energized OCS Components				Additional Clearance in Polluted Areas inches (mm)	Ancillary Conductors ~~Absolute~~ Minimum inches (mm)
	Normal ~~Minimum~~		~~Absolute~~ Minimum			
	C~~A~~ inches (mm)	P~~A~~ inches (mm)	C~~A~~ inches (mm)	P~~A~~ inches (mm)		
750 V dc	4 (105)	3 (80)	3 (80)	3 (80)	0 (0)	4 (105)
1500 V dc	5 (130)	3.5 (90)	4 (105)	3 (80)	0.5 (10)	5 (130)
3000 V dc	6 (155)	5 (130)	5 (130)	3 (80)	0.5 (10)	6 (155)
12.5 kV ac	7 (180)	6 (155)	6 (155)	4 (105)	0.75 (20)	7 (180)
25.0 kV ac	10.5 (270)	8 (205)	8 (205)	6 (155)	2 (50)	10.5 (270)
50.0 kV ac	21 (535)	16 (410)	16 (410)	12 (305)	4 (100)	21 (535)

C~~A~~ = Static Electrical Clearance for OCS Components
P~~A~~ = Passing Electrical Clearance for OCS Components
Note: Minimum Passing Mechanical Clearance = 3 (80)
Where feasible additional clearance should be provided.

2.2.6 CLEARANCES FROM ENERGIZED ANCILLARY CONDUCTORS (~~2010~~2020)

a. Typically, ancillary conductors, such as auxiliary feeders that electrically reinforce the OCS or parallel feeders used in auto-transformer systems, are tensioned in fixed termination mode so tensions and sags will vary with temperature and span length and, where appropriate, ice loading. Similarly, lateral offsets due to wind induced blow-off will vary dependent upon tension and span length. The clearance envelope shown in Figure 33-2-5 depicts these variations.

b. For general application throughout a system, it is recommended that mid-span clearance envelopes should be developed for each type of ancillary conductor, based on the anticipated range of ancillary conductor span lengths under all climatic and dynamic conditions. Table 33-2-2 provides ~~absolute~~ minimum clearances from ancillary conductors to grounded structures, which should be modified as indicated in Table 33-2-3 for systems installed above 3,000 ft. (900~~914~~ m).

c. At restricted clearance locations, such as overhead bridges, additional factors, such as localized wind gusting, animal intrusions or the formation of icicles, should be taken into consideration.

d. These clearance values are to be used only at locations that are protected from public access.

2.2.7 ALTITUDE COMPENSATION (2010~~)~~2020)

a. Air dielectric strength reduces with increased elevation. The design of the OCS for railroads and LRT systems operating above the 3,000-foot (~~914~~900 m) level must apply the altitude compensation factors shown in Table 33-2-3 or in accordance with the latest edition of the National Electrical Safety Code. Similar correction factors will apply to the design of any associated high-voltage transmission lines, or for parallel feeders in autotransformer systems, and for substation equipment, and should be considered in the design of third rail systems.

For Diagram, refer to Separate Attachment.

Figure 33-2-5. Clearance Requirements for Energized Ancillary Conductors

Table 33-2-3. Altitude Compensation – Adjustment of Electrical Clearances in Table 33-2-2

Altitude: feet (m)		Multiply by
0 – 3,000	(0-900~~914~~)	1.00
3,001~~0~~ – 4,000	(901~~914~~-1200~~1219~~)	1.02
4,001~~0~~ – 5,000	(1201~~1219~~-1500~~1524~~)	1.05
5,001~~0~~ – 6,000	(1501~~1524~~-1800~~1829~~)	1.08
6,001~~0~~ – 7,000	(1801~~1829~~-2100~~2134~~)	1.11
7,001~~0~~ – 8,000	(2101~~2134~~-2400~~2438~~)	1.14
8,001~~0~~ – 9,000	(2401~~2438~~-2700~~2743~~)	1.17
9,001~~0~~ – 10,000	(2701~~2743~~-3000~~3048~~)	1.20
10.001 – 12,000	(3001-3600)	1.25
12,001 – 14,000	(3601-4200)	1.30

2.2.8 DEPTH OF CONSTRUCTION OF THE OCS AT SUPPORTS (D) (~~2010~~2020)

a. The four minimum depths (D) of OCS construction normally used where supports are required below overpasses and through-truss bridges or in tunnels are shown in Table 33-2-4.

~~a.~~

Table 33-2-4. OCS Construction Depth (D)

Construction Type	inches	mm
Messenger-contact wire construction	6.0	155
Contact-wire-only construction (at supports)	4.5	115
Multiple contact-wire-only construction (between supports)	1.5	40
Single contact-wire-only construction (between supports)	0.75	20

b. Figure 33-2-3 indicates the System Height is measured from top of Messenger Wire (MW) to underside of Contact Wire (CW). If system height is defined in a different manner (say from centerline of MW to underside of CW, or from centerline of MW to centerline of CW), an allowance may have to be included for the appropriate wire radius or radii.

~~b.~~c. Where supports are required under a bridge or in a tunnel and suitable pockets to install the support hardware cannot be provided, the depth for contact-wire-only construction should be calculated on the basis of the depth at supports unless completely insulated support material can be used.

~~c.~~d. Support arms holding single or multiple contact wires in contact-wire-only construction shall restrict vertical movement - both up and down.

~~d.~~e. Additional clearance may be required to accommodate required electrical or mechanical clearances to the support arm insulator, as shown in Figure 33-2-4.

2.2.9 OCS CLEARANCE REQUIREMENT AT OVERHEAD STRUCTURES (H) (~~2010~~2020)

a. The clearance requirement (H) above the static vehicle height is depicted in Figure 33-2-3. Typical values for 750 V dc and 25 kV ac applications, using normal electrical clearances and other allowances, are shown in Table 33-2-5.

b. The following clearance requirement examples were computed for systems designed to operate below the 3,000-foot (~~914~~900 m) level. Clearances must be increased in accordance with Table 33-2-3 for elevations above 3,000 feet (~~914~~900 m).

Table 33-2-5. Clearance Requirements at Overhead Structures (H~~O~~)

Clearance Requirement	750 V dc		25 kV ac	
	inches	mm	inches	mm
OCS to underside of overpass bridge or tunnel deck = C or (P + U) ~~+ T_1~~ Table 33-2-2	5~~6~~	130~~155~~	10.5~~11.5~~	270~~295~~
MW installation tolerance, T_1 - Figure 33-2-3	1	25	1	25
Depth of OCS ~~including wire thickness,~~ assuming 500/350 kcmil for LRT and 300-300 kcmil for 25 kV~~, plus a system height of 6 in (155 mm)~~ = D	6~~6.5~~	155~~170~~	6~~6.25~~	155~~160~~
Allowance for CW Sag at mid-span, S_{cw} - Figure 33-2-3	2.5	65	2.5	65
CW installation tolerance, T_2 - Figure 33-2-3	1	25	1	25
Contact wire to top of load gauge or vehicle = C or (P + B) ~~+ T_2~~	5.5~~6.5~~	140~~170~~	10.5~~11.5~~	270~~295~~
Total OCS Clearance Requirement = H	21~~19~~	535~~495~~	31.5~~29.25~~	800~~750~~

Note: All values assumed to be Normal

2.2.10 VERTICAL CLEARANCE REQUIREMENTS AT OVERHEAD STRUCTURES (2010)R(2020)

a. Figure 33-2-3 shows the recommended basis for establishing the minimum required vertical clearance (V) beneath a fixed structure to accommodate construction of the OCS conductors between support positions. Where contact-wire-only construction is employed, versus messenger-contact catenary construction, the OCS depth (D) will be reduced, but may have to take into consideration the depth of parallel groove clamps or other clip devices that are used to secure the lateral position of the wires.

b. Figure 33-2-4 provides a pictorial representation of how the track and vehicle lateral tolerances should be combined with the vehicle and pantograph dynamic characteristics to establish the lowest practical operating position of the pantograph, from which the minimum value of V for the vertical structure opening can be determined.

c. The method by which super-elevation is achieved may vary among railroads and transit systems. In most systems, the low rail is considered to be the control rail and the high rail is lifted to achieve the required super-elevation, which must be taken into consideration when evaluating both vertical and lateral OCS and pantograph clearances.

d. Figure 33-2-4 shows the dimensional requirements needed to satisfy the minimum clearances for contact-wire-only construction mid-span between supports. As noted, additional clearance may be required at support points to accommodate the depth of the energized components of the support assembly. Electrical and/or mechanical clearances at support points may dictate the lowering of OCS wire heights. Alternatively, by making use of the space between deck support girders or by constructing pockets, it may be possible to provide the required additional clearance at the support so that the minimum mid-span clearances detailed in the diagram can be adopted.

e. In many cases, it is likely that the available clearance will be greater than V_{min}. The designer has three options for allocating the additional clearance. It is recommended that, wherever possible, the improvements should be made in the following order: (i) increase the clearance above the OCS, (ii) increase the clearance above the vehicle, and (iii) increase the system height at the supports. Increasing the clearance ABOVE the OCS should be the first priority, since this is the fixed situation, whereas clearance to the vehicle is normally of a temporary nature.

f. For railroad operations, allowances should be based on the designated FRA class of track and dynamic vehicle and pantograph deflections. For LRT operations, proposed track maintenance values should be used, together with dynamic vehicle and pantograph movements. Detailed engineering investigations may result in deviations - see Table 33-2-7 and Table 33-2-8.

2.2.11 LATERAL DISPLACEMENTS AND SUPER-ELEVATION (~~2010~~2020)

a. Figure 33-2-4 provides a pictorial representation of how the track and vehicle lateral tolerances should be combined with the vehicle and pantograph dynamic characteristics to establish the maximum lateral excursions of both the vehicle and the pantograph, thereby defining the Dynamic Vehicle Clearance Outline and the Dynamic Pantograph Clearance Outline, which should be used to establish the minimum lateral structure opening.

b. The assumption is made that the contact point of the pantograph is centered longitudinally over the truck pivot point of the locomotive, EMU or LRT car. Where this is not the case, additional lateral clearance on curved track sections must be determined from the exact geometry of the pantograph passage through curves and turnouts. In these circumstances, the projected pantograph centerline is separated from the elevated truck centerline and all OCS supports on curved sections should be aligned to relate to the pantograph centerline. Where the contact wire is off-center in relation to the pantograph, account must be taken of additional side-tilting of the pantograph and clearances adjusted accordingly.

c. The limits of dynamic movement of rolling stock will vary considerably according to type of equipment and track conditions. The lateral displacement values shown in Table 33-2-7 and Table 33-2-8 for LRT and EMU cars, and for Locomotives, have been developed by manufacturers of these types of equipment, or verified by operating experience.

d. The English values for maximum super-elevation in Table 33-2-6 have~~has~~ been based on 6 inches which results in a lateral displacement of 26.6 inches at a height of 22 feet above top of rail. By comparison, the

Metric values are based on a maximum super-elevation of 150 mm which results in a lateral displacement of 666 mm at a height of 6.70 m above top of rail. The method by which super-elevation is achieved may vary among railroads and transit systems. In most systems, the low rail is considered to be the control rail and the high rail is lifted to achieve the required super-elevation, which must be taken into consideration when evaluating both lateral and vertical OCS and pantograph clearances.

e. The Cross-Level Allowance (E) provides for the super-elevation deficiency maintenance allowance (positive or negative on either rail). It does not allow for curved track super-elevation effects. On this basis, the sway of the vehicle and pantograph, due to super-elevation deficiency, becomes symmetrical about the track centerline from a design perspective.

f. The largest element of the dynamic movement of the pantograph is due to the vehicle roll (R) on its suspension. To compute these effects at the uplifted contact wire level, the height of the Vehicle Roll Point above rail level must be known, together with the Roll Angle of the vehicle under both normal and emergency operating conditions. For normal operational analyses of the pantograph-contact wire interface, the roll allowance should be based purely on the dynamic characteristics of the vehicle and pantograph. However, for emergency operating conditions, the effects resulting from a failed vehicle suspension, such as broken springs or damaged air bags, should be considered in evaluating the clearance from the pantograph to fixed wayside structures. It is recommended that vehicles with damaged or failed suspensions be removed from the system as quickly as possible, but at very restricted speeds.

g. The lateral displacements shown in the clearance diagram Figure 33-2-4, and detailed in the examples in Table 33-2-7 and Table 33-2-8, are based on the specified types of FRA Class of Track, which may or may not be applicable to LRT systems. (For FRA requirements, refer to 49 CFR, Chapter 2, Para. 213.63 for Class 1-5, and 49 CFR, Chapter 2, Para. 213.331 for Class 6-9). For other classes of track or other levels of guaranteed minimum maintenance tolerances, the dimension (S) must be adjusted in accordance with appropriate detailed engineering investigations.

Table 33-2-6. Super-elevation Allowance (E) – Allowance at Pantograph/Contact Wire Level

Super-elevation Effect (E) – inches for Pantograph Height above Rail – feet				**Super-elevation Effect (E) – mm for Pantograph Height above Rail – meters**			
Super-elevation inches	16	19	22	Super-elevation mm	4.85	5.80	6.70
1	3.2	3.8	4.4	25	80	96	111
2	6.5	7.7	8.9	50	161	192	222
3	9.7	11.5	13.3	75	241	288	333
4	12.9	15.3	17.8	100	321	384	444
5	16.1	19.2	22.2	125	401	480	555
6	19.4	23.0	26.6	150	482	576	666

Note: In calculations and clearance evaluations, the Cross-Level or Super-elevation Effect should be assessed at the uplifted contact wire height and should be based on **Rail Head Centers**, the points where the vehicle wheels sit on the rail heads and which, for a nominal track gauge of 4’- 8½” (1435 mm), is **59.5 inches (1510 mm)**.

Publisher – please Insert Table

Table 33-2-7 Examples of Lateral Displacements of Pantographs (S) – English
~~Please refer to attached spreadsheet~~

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Table 33-2-8 Examples of Lateral Displacements of Pantographs (S) – Metric
~~*Please refer to attached spreadsheet*~~

2.3 CALCULATION OF VERTICAL AND LATERAL STRUCTURE OPENINGS (~~2010~~2020)

2.3.1 FORMULAE (~~2010~~2020)

a. Two basic formulae have been developed to determine the vertical and horizontal structure opening for various voltages as shown on Figure 33-2-3 and Figure 33-2-4 and Table 33-2-9:

2.3.1.1 Vertical Structure Opening (V) – refer to Figure 33-2-3

$$V = P_A + U + T_1 + D + S_{cw} + T_2 + P_A + B + Y + T_3$$

~~i~~If $P_A + U$ or $P_A + B$ are less than C_A, then C_A should be used

where:

C_A = Static Electrical Clearance – refer to Table 33-2-2
P_A = Passing Electrical Clearance – refer to Table 33-2-2
U = OCS Uplift due to pantograph pressure and operating conditions = 0.5 inch (13mm) minimum, 2 inch (50mm) normal for overpasses. Allowances for tunnels require detailed analysis.
T_1 = Tolerance for OCS construction and maintenance
D = Depth of OCS, varies based upon design parameters and available headroom (see Article 2.2.8)
S_{cw} = Worst case Sag of Contact Wire between supports
T_2 = Tolerance for OCS construction and maintenance
P_A = Passing Electrical Clearance – refer to Table 33-2-2
B = Dynamic vehicle bounce allowance
Y = Static Vehicle Load Height – refer to AAR Plate Diagrams and Chapter 28 for Railroad Clearances, or to the Vehicle Design Criteria for LRT Systems
T_3 = Tolerance for track construction and maintenance

~~A subscript =~~For Altitude compensation factors for electrical clearance for OCS constructed above 3,000 feet (~~914~~900 m) ~~—~~refer to Table 33-2-3

2.3.1.2 Lateral Structure Opening for the Pantograph (W)

$$W = X + 2L + 2S + 2P_A + 2E$$

where:

X = Pantograph, width of live portion of head
L = Lateral shift of track within civil engineer's tolerance – 1.0 inch maximum, or in accordance with FRA Track Standards
S = LRT car, EMU car or Locomotive sway (roll effect) – Table 33-2-7 or Table 33-2-8
P_A = Lateral electrical clearance of pantograph to side of tunnel, bridge arch or abutment under passing conditions - Table 33-2-2 and Table 33-2-3
E = Lateral allowance for super-elevation deficiency where applicable

~~A subscript =~~For Altitude compensation factors for electrical clearance for OCS constructed above 3,000 feet (~~914~~900 m) ~~–~~refer to Table 33-2-3

Table 33-2-9. Total Clearance (H) above Static Vehicle Height using Typical Dimensions

$H = P_A + U + T_1 + D + S_{cw} + T_2 + P_A + B$ (formula and elements are based on Figure 33-2-3)

Nominal System Voltage	Total OCS Clearance (H): inches (mm) (for Altitudes below 3000 feet / ~~914~~900 m)			
	Normal		Minimum	
750 V dc	21~~18.5~~	535~~(480)~~	15~~14~~	385~~(367)~~
1500 V dc	22~~19.5~~	560~~(500)~~	15~~14~~	385~~(367)~~
3000 V dc	25~~22.5~~	635~~(580)~~	15~~14~~	385~~(367)~~
12.5 kV ac	27~~24.5~~	690~~(630)~~	17~~16~~	435~~(417)~~
25 kV ac	31~~28.5~~	790~~(730)~~	21~~20~~	535~~(517)~~
50 kV ac	47~~44.5~~	1195~~(1140)~~	33~~32~~	840~~(817)~~

Note 1. Actual total clearances measured above static vehicle height may vary due to local site specific parameters.

Note 2. Minimum clearances should only be used in extreme cases. The engineering responsibility should include a full understanding of local circumstances, including the possible consequences of using ~~absolute~~ minimum electrical clearances as discussed in Section 2.2.1 above.

Note 3. Adjustment of component items is needed for OCS installations at elevations above 3,000 feet (~~914~~900 m); see Table 33-2-3.

Note 4. The values quoted above assume an OCS system depth (D) of 6 inches (155 mm) for both dc and ac systems, including energized support hardware).

2.3.2 SAMPLE CALCULATIONS (~~2010~~2020)

2.3.2.1 Vertical Structure Opening (V)

Two sample calculations are provided, which demonstrate the effect that differences in system voltage and size of rolling stock (that is to be accommodated) have on the determination of the required vertical structure opening. Some of the values have been selected arbitrarily for completeness and may require increasing or decreasing for a site specific application.

a. To accommodate a **750 V dc Catenary System** with a system height of 6" (155 mm), operating at an elevation below 3,000-feet (~~914~~900 m) above a Plate 'H' load gauge of 20'- 3" (6.07 m), which assumes joint-use operations with freight, the vertical height requirement above top of rail to a bridge structure over railroad tracks that are electrified (or are proposed for electrification) may be calculated as follows. Note that for ballasted track, the final vertical opening shall equal V + 6" for future track raising.~~:~~

$$V\text{~~H~~} = P_{\text{~~A~~}} + U + T_1 + D + S_{cw} + T_2 + P_{\text{~~A~~}} + B + Y + T_3$$

English: V~~H~~ = 3"+2"+1"+6"+2.5”+1"+3"+2.5"+20'- 3"+1.5" = 22’- 1.5”~~21'-11" + 6” track raise = 22'-5"~~

Metric: V~~H~~ = 80+50+25+155+65+25+80+65+6175+40 = 6.720~~6.695~~ m~~ + 155 mm track raise = 6.85 m~~

b. To accommodate a **25 kV ac Catenary System** with a system height of 6" (155 mm), operating at an elevation below 3,000-feet (~~914~~900 m) above a Plate ‘F’ load gauge of 17'- 0" (5.18 m), the vertical height requirement above top of rail to a bridge structure over railroad tracks that are electrified (or are proposed for electrification) may be calculated as follows. Note that for ballasted track, the final vertical opening shall equal V + 6” for future track raising.~~:~~

V~~H~~ $= (P_A + U) + T_1 + D + T_2 + (P_A + B) + Y + T_3$

English: V~~H~~ = (10.5")+1"+6"+2.5”+1"+(8"+2.5")+17'- 0"+1.5" = 19’- 9”~~19'-6.5" + 6” track raise = 20'-0.5"~~

Metric: V~~H~~ = (270)+25+155+65+25+(205+65)+5180+40 = 6.030~~5.965 m + 155 mm track raise = 6.12 m~~

c. Under static conditions, (P~~A~~ + U) becomes C for the 25 kV system, and (P~~A~~ + B) = C. Other tolerances and allowances may also need to be replaced by the normal amounts for the static conditions.

d. Electrical clearance calculations are based on a highway structure or bridge crossing at right angles to the track and centered at the mid-span point in the OCS. At other angles, catenary system heights will vary and at the points of support may have to be 5'- 0" (1.52 m) or more where attachment to the overhead structure has to be avoided. Adjustments for the OCS depth at the actual point of crossing must therefore be made accordingly, or contact-wire-only construction considered.

2.3.2.2 Lateral Structure Opening

Two sample calculations are provided. These demonstrate the effect that differences in system voltage, size of pantograph (that is to be used) and operating contact wire height have on the determination of the required lateral structure opening, since the lateral structure opening depends on the sway of the vehicle, the LRT, EMU, or locomotive pantograph width and sway, electrical clearance to the side of the structure, permissible track super-elevation deficiency and track maintenance tolerances.

a. To accommodate a **750 V dc Catenary System**, the lateral displacement of the pantograph under normal operating conditions may be calculated as detailed below, assuming 3 degrees of LRT vehicle roll over track that is maintained to standards equivalent to FRA Class 3 at an elevation below 3,000-feet (~~914~~900 m).

b. The English unit calculation assumes LRT vehicles equipped with a 6'- 0¾" pantograph, running under a contact wire at 22 feet above top of rail with 6 inches of uplift, and with 1¾ inches of permissible super-elevation deficiency.

c. By comparison, the Metric calculation assumes LRT vehicles equipped with an 1850 mm pantograph, running under a contact wire at 6.70 m above top of rail with 150 mm of uplift, and with 45 mm of permissible super-elevation deficiency.

$$W = X + 2(L) + 2(S) + 2(P_A) + 2(E)$$

English: W = 72.75 + 2(4.41) + 2(17.92) + 2(3) + 2(5.96) = 135.33~~125.33~~ inches or 11.28~~10.27~~ ft; Say = 11.5~~10.5~~ ft

Metric: W = 1850 + 2(113) + 2(454) + 2(76) + 2(153) = 3442 mm or 3.44 m; Say = 3.5 m

d. To accommodate a **25 kV ac Catenary System**, the lateral displacement of the pantograph under normal operating conditions may be calculated as detailed below, assuming 3 degrees of EMU vehicle roll over track that is maintained to standards equivalent to FRA Class 5 at an elevation below 3,000-feet (~~914~~900 m).

e. The English unit calculation assumes EMU vehicles equipped with a 6'- 6" pantograph, running under a contact wire at 19 feet above top of rail with 6 inches of uplift, and with 1 inch of permissible super-elevation deficiency.

f. By comparison, the Metric calculation assumes EMU vehicles equipped with a~~n~~ 1980 mm pantograph, running under a contact wire at 5.80 m above top of rail with 150 mm of uplift, and with 25 mm of permissible super-elevation deficiency.

$$W = X + 2(L) + 2(S) + 2(P_A) + 2(E)$$

English: W = 78.0 + 2(2.52) + 2(12.0) + 2(8) + 2(2.56) = 128.16 inches or 10.68 ft; Say = 11 ft

Metric: W = 1980 + 2(68) + 2(306) + 2(205) + 2(64) = 3266 mm or 3.27 m; Say = 3.4 m

g. Caution must be exercised in relating electrical clearances from insulators, since apparent creepage dimensions may vary due to the numerous designs available and the wide variety of insulator configurations in use.

~~**NOTE: It must be recognized that the requirements for total vertical clearance and total lateral clearance will vary dependent upon the selected operating voltage, vehicle and pantograph size, and track conditions, including track curvature and super-elevation, and that these clearance requirements differ for dynamic passing situations and stationary static situations. These guidelines provide the means to identify all of the relevant allowances, which must be considered in determining the required clearances, but do not direct the user to a particular conclusion, since design decisions can only be made with a full understanding of the actual circumstances involved.**~~

END OF SECTION

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