APTA STANDARDS PROGRAM
RECOMMENDED PRACTICE

APTA PR-CS-RP-003-98, Rev. 2
First Published: March 26, 1998
First Revision: March 22, 2004
Second Revision: April 24, 2024

PRESS Construction & Structural Working Group

Developing a Clearance Diagram for Passenger Equipment

Abstract: This recommended practice provides a guide for passenger railroads to determine their particular equipment clearance requirements and develop a clearance diagram sufficiently specific to allow equipment designers to develop designs that will conform to those requirements.

Keywords: clearance diagrams

Summary: Section 1 guides the user to the appropriate subsequent sections based on the passenger railroad's track ownership. Section 2 provides a checklist of steps to take in defining the clearance requirements for equipment (locomotives and cars) to be operated on a passenger railroad's own track, together with some specific recommendations. Section 3 describes the steps to take in defining the clearance requirements for equipment to be operated only on another railroad's track. Section 4 describes the steps to take in combining the clearance requirements for a passenger railroad's own track with those for another railroad's track.

Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the manual for the APTA Standards Program. This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Construction and Structural Working Group as directed by the Passenger Rail Equipment Safety Standards Policy and Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any recommended practices or guidelines contained herein is voluntary. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit system's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This document supersedes APTA PR-CS-RP-003-98, Rev. 1, which has been revised. Below is a summary of changes from the previous document version:

- Deleted section references if they were linear in the document.
- Updated "Scope and purpose," "Abstract" and "Introduction."
- Added a block diagram to Section 1.
- Added supplemental clearance table.
- Change top of rail vehicle clearance from 2 in. to 2.5 in. per Code of Federal Regulations.
- Removed references to PASCLEAR spreadsheet.

Table of Contents

List of Figures and Tables

Participants

The American Public Transportation Association greatly appreciates the contributions of the **Construction and Structural Working Group**, which provided the primary effort in the drafting of this document.

The following subject matter experts participated contributed to Revision 2 of this standard:

Ryan Taylor, Chair, *Hatch*

Iman Ashtiani, *Alstom*
Joseph Kenas, *Alstom*
Frank Maldari, *MTA Long Island Rail Road*
Eloy Martinez, *Self*
Mehrdad Samani, *Jacobs*
Benjamin Spears, *Hatch*
Stuart Trout, *Retired*

At the time this standard was completed, the working group included the following members:

Martin Young, Chair, *Sound Transit*
Mehrdad Samani, Vice Chair, *Jacobs*
Francis Mascarenhas, Secretary, *Metra*

Gabriel Amar, *Systra*
Enrique Arroyo-Rico, *Alstom*
Juan Barahona, *Talgo*
Evelyne Berthomme, *Alstom*
Shafal Bhushan, *Baker Bellfield*
Martin Bigras, *Alstom*
Robert Bocchieri, *ARA*
James Brooks, *Utah Transit Authority*
Paul Callaghan, *Transport Canada*
Julia Camacho, *Talgo*
Luiz Cano-Fernandez, *Alstom*
Bruce Cardon, *Metro Transit*
Michael Carolan, *Volpe Center*
Mike Cook, *Hatch*
Robert Cook, *SCRRA*
Josh Coran, *Talgo*
Sean Cronin, *Metra*
Felipe Czank, *Alstom*
Francois Duchaine, *Alstom*
Harold Ellsworth, *Motive Power*
Shaun Eshraghi, *Volpe Center*
Steve Finegan, *AtkinsRéalis*
Christian Forstner, *Seisenbacher Rail Interiors*
Andre Gagne, *Alstom*
Michael Gill, *AtkinsRéalis*
Garrett Goll, *Voith*
Jeffrey Gordon, *Federal Railroad Administration*
Travis Grohum, *ENSCO Rail*
Glenn Gough, *Siemens Mobility*
Yosi Grunberg, *WSP*
Christian Gschnizter-Baernthaler, *Stadler*
Dong Keun Ha, *SCRRA*
Nicholas Harris, *Hatch*
Jason Hesse, *STV*
Hunter Halverston, *Stadler*
Karina Jacobsen, *Volpe Center*
Paul Jamieson, *Retired*
Robert Jones, *Stadler*
Larry Kelterborn, *LDK Advisory*
Joseph Kenas, *Alstom*
Steven Kirkpatrick, *Applied Research Associates*
Rick Komm, *Kiel NA*
Lukasz Kozdeba, *Canadian Railway Services*
Pierre Laberge, *Alstom*
Jean-Pierre Lapointe, *Alstom*
Peter Lapre, *Federal Railroad Administration*
Dominique Le-Corre, *Alstom*
Ana Maria Leyton, *Transport Canada*
Patricia Llana, *Volpe Center*
William Luebke, *Kiel NA*
Robert MacNiell, *Simpson, Gumpertz, & Heger*
Frank Maldari, *MTA Long Island Rail Road*
James Marks, *Canadian Railway Services*
Eloy Martinez, *Self*
Robert Mayville, *Retired*
Patrick McCunney, *AtkinsRéalis*

James Michel, *Retired*
Tomoyuki Minami, *JR Central*
Juergen Neudorfsky, *Seisenbacher Rail Interiors*
Steven Orzech, *Freedman Seating*
Chase Patterson, *Voith*
Thomas Peacock, *AtkinsRéalis*
Brian Pitcavage, *Hatch*
Benoit Poulin, *Alstom*
Anand Prabhakaran, *Sharma & Associates*
Matthew Raun, *Stadler*
Denis Robillard, *Baultar Concept*
Thomas Rutkowski, *Brightline Trains Florida*
Jean-Francois Savaria, *Alstom*
Bryan Sawyer, *Utah Transit Authority*
Brian Schmidt, *SJRRC*
Gerhard Schmidt, *Siemens Mobility*
Martin Schroeder, *Jacobs*
Fredric Setan, *Alstom*
Kristine Severson, *Volpe Center*
Melissa Shurland, *Federal Railroad Administration*
Gunneet Singh, *Hatch*
Benjamin Spears, *Hatch*
Rick Spencer, *Knorr Brake Corp*
Jeremy Spilde, *Metro Transit*
Alois Starlinger, *Stadler*
Laura Sullivan, *Volpe Center*
Lukasz Szymsiak, *VIA Rail*
Medhi Taheri, *Raul V. Bravo & Associates*
Jason Thomas, *Metra*
Michael Trosino, *Amtrak*
Stuart Trout, *Retired*
Rudy Vazquez, *Amtrak*
Clifford Woodbury, *Hatch*
Tamer Yassa, *Transport Canada*
Theresa Zemelman, *Raul V. Bravo & Associates*
Steven Zuiderveen, *Federal Railroad Administration*

Project team
Nathan Leventon, *American Public Transportation Association*

Introduction

This introduction is not part of APTA PR-CS-RP-003-98, "Developing a Clearance Diagram for Passenger Equipment."

This recommended practice applies to all:

- railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
- railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This recommended practice may apply to:

- rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
- tourist, scenic, historic, host railroads or excursion operations, whether on or off the general railroad system of transportation;
- operation of private cars, including business/office cars and circus trains unless otherwise required by other standards or regulations; or
- railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

The Association of American Railroads maintains clearance diagrams governing the interchange of freight cars among railroads. There are five such diagrams: AAR plates B, C, E, F and H. Plate B is the oldest and least generous of the five, and there are no restrictions on the movement of cars meeting its requirements. The other four diagrams have been developed in response to new types of freight cars. Cars designed to the requirements of these diagrams are restricted from certain portions of the railroad network.

AAR also developed a clearance diagram for unrestricted interchange of passenger cars. It was adopted as Standard S-035 in 1952 and was revised in 1953. It appears on page A-III-10 of AAR's *Manual of Standards and Recommended Practices*, Section A, Part III. Section A is out of print and no longer maintained by AAR. Many passenger cars not meeting the requirements of Standard S-035 have been built, but each such design had to be specially cleared for the routes over which it was to operate.

There are many differences between the passenger car clearance diagram and the various freight car clearance diagrams. The passenger car clearance diagram is more restrictive in height. It is also more restrictive with respect to maximum car width, although it allows greater overhang on curves. There are also some differences in the shapes of the diagrams at the top and at the bottom, presumably because of restrictions such as station platforms, platform canopies and third rails that occur only in passenger facilities or on passenger tracks.

Since Amtrak was created in 1971, it has developed its own clearance diagrams. Since Amtrak operates the majority of intercity passenger service in the continental United States, it has not been faced with the same concern over interchangeability that existed when such services were operated by a multiplicity of railroads. Amtrak has generally required that new commuter equipment to be operated on its track must meet the provisions of its clearance diagrams. This restriction does not exist if the equipment is to be operated on a freight railroad or on a commuter railroad's own track.

In summary, there is little standardization of passenger car clearance requirements. Passenger cars constructed to AAR Standard S-035 may not meet the requirements of Amtrak's clearance diagrams. This is also true of much commuter equipment. Consequently, each passenger railroad is faced with the task of determining its particular clearance requirements.

During its investigation into passenger car clearance diagrams, APTA concluded that one or more universal passenger car clearance diagrams would not be feasible, because a diagram containing the most restrictive conditions of each passenger railroad would probably not be acceptable to any of them. Consequently, APTA opted to produce a procedure that could be followed by individual passenger railroads to develop their own clearance diagrams. This procedure identifies the various factors that should be taken into account and explains how they affect the final diagram.

Scope and purpose

This recommended practice provides a guide for passenger railroads to (1) determine their particular equipment clearance requirements and (2) develop a clearance diagram sufficiently specific to allow equipment designers to develop designs that will conform to those requirements. It has three specific limitations:

1. It is not intended to lead to the development of a universal passenger equipment diagram, because such a diagram would be too restrictive in one way or another to most passenger railroads.

2. It is based on truck types that do not consider tilt suspension systems. If a tilt suspension is employed, then these procedures may have to be modified to suit the particular vehicles.
3. The details in this recommended practice are provided for known existing designs. The passenger railroad needs to review the specific design to ensure that all variables are accounted for.

The procedure outlined in this recommended practice is based on facts and principles that are well-understood in the railroad industry. It is the responsibility of the railroad to validate the procedure and the results prior to implementation.

Sections 1–3 of this recommended practice help the user through the process of developing the information necessary to establish an equipment clearance diagram, as follows:

- **Section 1** guides the user to either Section 2 or Section 3 based on the ownership of the track over which the passenger railroad operates.
- **Section 2** provides a checklist of steps to take in defining the clearance requirements for equipment (locomotives and cars) to be operated on a passenger railroad's own track, together with some specific recommendations. It is broken down into fixed obstructions along the right-of-way (Section 2.1), legal clearance restrictions (Section 2.2), equipment characteristics (Section 2.3), and track irregularities (Section 2.4). It also contains instructions for combining that information into a single diagram (Section 2.5).
- **Section 3** describes the steps to take in defining the clearance requirements for equipment to be operated on another railroad's track.

If the particular passenger railroad's equipment is operated both on its own and on other railroad's tracks, the steps in both sections 2 and 3 apply. The final clearance diagram should take into consideration the most restrictive conditions that exist on any of the lines over which the equipment will be operated, as described in Section 4.

Developing a Clearance Diagram for Passenger Equipment

1. General approach to establishing a clearance diagram

The purpose of this recommended practice is to develop a passenger equipment clearance diagram based on wayside conditions and based on existing equipment that does not have any known clearance issues.

> **NOTE:** Checked items in **bold print** throughout sections 1–4 provide a checklist of actions to be taken in developing a clearance diagram.

The approach to be followed in establishing a clearance diagram for a passenger railroad's equipment will vary depending on where the equipment is to be operated:

- only on track owned by the passenger railroad
- both on track owned by the passenger railroad and on track owned by another railroad
- only on track owned by another railroad

Therefore, the following steps are necessary:

✓ **Identify ownership of the track over which the equipment will operate.**

✓ **Refer to Table 1 to see which sections of this document are applicable.**

TABLE 1
How to Use This Document

If Territory Is Owned…	Read Sections
Only by operating railroad	1, 2
By operating railroad and by another railroad	1, 2, 3
Only by another railroad	1, 2, 3, 4

Each of the subsections in sections 2 and 3 contain a list of steps to be followed to develop sufficient information on the particular topic.

2. Equipment clearance diagram for passenger railroads that own their own track

The following four separate sets of factors must be considered when developing a clearance diagram for passenger railroads that own their own track:

- fixed obstructions along the right-of-way (Section 2.1)
- legal restrictions within the states in which trains will be operated (Section 2.2)

- physical characteristics of the equipment to be operated (Section 2.3)
- track irregularities (Section 2.4)

Sections 2.1 and 2.2 are used to develop a right-of-way composite diagram that is used as an input to the equipment clearance diagram. The steps to be followed in combining them into a single clearance diagram are described in Section 2.5.

2.1 Fixed obstructions along track owned by the passenger railroad

✓ **Develop a composite diagram of the most limiting conditions along the right-of-way.**

A suggested method for charting all obstructions along the right-of-way is presented in Chapter 28, Section 3.3, of the AREMA (formerly AREA) *Manual for Railway Engineering*. It consists of developing a composite diagram in a plane transverse to the track on which the following are drawn:

- The most limiting obstructions around the complete perimeter of the space through which the equipment will operate.
- The location of each obstruction.
- When an obstruction is not on tangent track, record the track curvature.
- When an obstruction is not on tangent track, record the superelevation.
- Maximum authorized speeds at each obstruction. The authorized speed can be determined from the railroad's operating timetable.

2.2 Legal clearance restrictions

✓ **Review legal clearance requirements for the states in which the equipment will operate.**

Legal clearance requirements for the various states and the District of Columbia are summarized in simplified form in the table in Chapter 28, Section 3.6, of the AREMA *Manual for Railway Engineering*. The limiting dimensions for platforms shown in columns 24–29 are of particular concern.

Since this table is merely a summary, the full text of an individual state's clearance regulation should be reviewed if there is a question about any of the limiting dimensions shown.

✓ **Add to the composite diagram any legal requirements that are more limiting than the restrictions already identified.**

Any clearance limitations from the table in Chapter 28, Section 3.6, of the AREMA *Manual for Railway Engineering* that are more restrictive than the limitations identified in Section 2.1 should be added to the right-of-way restriction diagram developed in that section.

At this point the composite diagram will contain all the most restrictive physical and legal limitations. However, this diagram is not adequate as an equipment clearance diagram for the following reasons:

- The effect of track curvature at the point of obstruction has not yet been evaluated.
- Lateral displacement of equipment permitted by design tolerances and by equipment and track component wear must be considered.
- Vertical and angular body displacement caused by spring deflection must be considered.
- This diagram is based on track that has a defined curvature and elevation. Therefore, a safety factor must be incorporated to allow for further displacements caused by track variations from the standard (defined) condition.

2.3 Equipment characteristics

Typically, existing equipment is used as the basis for developing a clearance diagram. To develop a clearance diagram, certain pertinent equipment characteristics need to be gathered. These characteristics fall into two general categories. The first category consists of fixed dimensions or dimensional limitations that may be defined in advance for all equipment and are discussed in Section 2.3.1. The second category consists of factors that cannot be defined with fixed values because they vary with the type of equipment and are discussed in Section 2.3.2.

If existing equipment is not used, then the information contained in sections 2.1 and 2.2, along with the fixed equipment dimensions in Section 2.3.1, should be used to create an equipment clearance diagram.

2.3.1 Fixed equipment dimensions and dimensional limitations

Certain basic equipment dimensions can be either defined or limited in advance to simplify the process of constructing an equipment clearance diagram. These include the distance between truck centers, the extreme width and the minimum clearance above the top of the rail. These three dimensions are discussed in sections 2.3.1.1, 2.3.1.2 and 2.3.1.3, respectively.

2.3.1.1 Truck centers

- ✓ **Select the distance between truck centers on which the equipment clearance diagram is to be based.**

The center and end overhang of equipment on curves must both be considered in determining clearances. Since the amount of overhang at both the center and the ends of the vehicle varies with the distance between truck centers, it is necessary to specify a distance between truck centers as the basis for the clearance diagram. Passenger cars are longer than passenger locomotives, so it is the cars that govern in selecting this dimension.

The end overhang of a railroad car is a function of both the distance between truck centers and the overall length of the car. As a general rule, the car designer prefers to select a distance between truck centers that will equalize the center and end overhang as much as possible, thereby optimizing the car width. Typically, these parameters result in a car that is 85 ft long with 59 ft, 6 in., truck centers. In practice, however, there may be other design considerations that affect the truck placement.

2.3.1.2 Extreme width

- ✓ **Establish the extreme width permissible at any point throughout the height of the equipment.**

If the equipment is going to be used in interchange service, even during delivery to the purchaser, it is recommended that the extreme width not exceed 10 ft, 6 in., (3.20 m) at any point throughout its height regardless of right-of-way obstructions. In no case should the extreme width exceed 10 ft, 8 in. (3.25 m). These maximum width limitations are based on AAR Plates B and C.

Note that there may be flexible appurtenances, such as side mirrors, that exceed this requirement. These exceedances should be considered on a case-by-case basis as agreed between the purchaser and the carbuilder.

2.3.1.3 Minimum clearance above top of rail

- ✓ **Establish the minimum acceptable clearance above the top of the rail under the most severe conditions of wear and spring deflection.**

It is recommended that the minimum clearance above the top of the rail for all parts of the car except the wheels, flexible nonmetallic sand pipe extension tips, and trip cock arms, be 2.5 in. (6.3 cm) (see 49 CFR §229.71). This limitation should apply under the most severe conditions of wear and dynamic spring deflection. In the case of air springs, the most severe deflection occurs with fully deflated spring and deflection of the air spring support due to maximum passenger loading.

2.3.2 Design dependent equipment characteristics

> **NOTE:** The following discussion is based on the use of conventional types of trucks and does not consider tilt suspension systems. If an unconventional truck design or a tilt suspension is employed, these procedures may have to be modified to suit the particular vehicles.

The extreme lateral and vertical displacement and roll of the vehicle body from its normal position is affected by various design parameters, wear limits, suspension characteristics and track irregularities. There are two ways to deal with these factors.

The first way is to analyze each individually and combine the results. Design parameters are discussed in Section 2.3.2.1, wear limits in Section 2.3.2.2, suspension characteristics in Section 2.3.2.3, and track irregularities in Section 2.4.2.

✓ **If this approach is to be followed, go to Section 2.3.2.1.**

The alternative is to perform a static test and apply appropriate correction factors in a procedure outlined by AREMA. This is discussed in Section 2.3.2.3.

✓ **If this approach is to be followed, go to Section 2.3.2.3.**

2.3.2.1 Lateral design parameters

Design parameters that affect the lateral displacement of the body must be considered. The parameters listed below need to be considered for all types of equipment. Other parameters specific to the equipment design must also be considered. Appendix A provides a very simple example considering a typical bolstered truck.

1. Lateral tolerance between wheels and rails

Two types of flanges are permitted on railroad wheels: narrow and wide. The maximum lateral movement $\mathbf{T_1}$ possible for a new wheel set centered on in-gauge track is a function of the flange type and is determined by **Formula 1**:

> **CAUTION:** Use only English units in formulas in this recommended practice.

$$\begin{aligned} \mathbf{T_1} &= \mathbf{0.5[g_t - (g_w + 2f_n)]} \\ &= \mathbf{0.59375\ in.\ for\ narrow\text{-}flange\ wheels} \\ &= \mathbf{0.375\ in.\ for\ wide\text{-}flange\ wheels} \end{aligned} \quad \textbf{(1)}$$

where:
$\mathbf{g_t}$ = standard track gauge at a point ⅝ in. below top of rail = 56.5 in.
$\mathbf{g_w}$ = minimum gauge of wheel set between backs of flanges = 53 in.
$\mathbf{f_n}$ = minimum thickness of new wheel flange = 1.15625 in. for narrow flange or = 1.375 in. for wide flange

Determine the maximum total lateral movement of the body with respect to the track resulting from design tolerances by the formula $\mathbf{T_{tot} = T_1 + T_{1+n}}$**…** ($\mathbf{T_{1+n}}$ will be dependent on truck design).

2.3.2.2 Wear limits

Wear that affects the lateral displacement of the body must be considered. The parameters listed below need to be considered for all types of equipment. Other parameters specific to the equipment design must be considered. Appendix A provides a very simple example considering a typical bolstered truck.

1. Wheels

The minimum allowable thickness of a wheel flange (under AAR rules) is $^{15}/_{16}$ in. (2.38 cm). Flange wear translates directly into increased lateral displacement. The maximum permissible reduction in flange thickness $\mathbf{W_1}$ is determined by **Formula 2**.

> **CAUTION:** Use only English units in formulas in this recommended practice.

$$\mathbf{W_1 = f_n - f_c} \qquad (2)$$

where:
- $\mathbf{f_n}$ = minimum thickness of new wheel flange = 1.15625 in. for narrow flange or 1.375 in. for wide flange
- $\mathbf{f_c}$ = condemning thickness of wheel flange = 0.9375 in.

Using AAR limits, therefore, $\mathbf{W_1}$ = 1.15625 in. − 0.9375 in. = 0.625 in. for narrow-flange wheels, and $\mathbf{W_1}$ = 1.375 in. − 0.9375 in. = 0.4375 in. for wide-flange wheels. If the passenger railroad uses a different condemning limit for flange thickness, these calculations must be adjusted accordingly.

Determine the maximum total lateral movement of the body with respect to the track resulting from wear by the formula $\mathbf{W_{tot} = W_1 + W_{1+n}}$ ($\mathbf{W_{1+n}}$ will be dependent on the truck design.)

2.3.2.3 Suspension characteristics

The following equipment characteristics related to the suspension system affect the amount of static lean of the vehicle on elevated track:

1. Height of center of gravity of body above top of rail

When the center of gravity (c.g.) of the vehicle body is offset from the center of roll rotation, it applies a moment to the trucks that will increase the load on the primary and secondary suspension (and, therefore, the spring compression) on the side toward which the offset occurs and decrease it on the other side.

For new vehicles, the body c.g. height should be available from the manufacturer. Since the worst case of body lean needs to be identified, this c.g. should be for the fully loaded vehicle. If only the empty-vehicle c.g. is available, it will need to be modified to reflect the loaded condition.

2. Height of roll rotation above top of rail

The center of roll rotation is the point about which the body rotates on the trucks. The moment arm through which the center of gravity operates when the vehicle is on elevated track is a function of the roll rotation height, the c.g. height and the amount of elevation.

3. Spring rate

The spring rates can be supplied by either the spring manufacturers or the truck manufacturers (usually expressed in pounds per inch).

There are suspension designs in which two different kinds of springs are stacked (e.g., a steel coil spring on top of an air spring) or there is an additive effect due to spring geometry (e.g., swing arm type primary suspension). In such a case, the composite spring rate must be calculated or obtained from the truck manufacturer.

4. Lateral distance between center of spring(s) and longitudinal centerline of vehicle

The lateral distance between the center of the spring(s) and the centerline of the vehicle is the moment arm that determines the compressive force on the spring(s) resulting from the moment created by the offset of the body c.g.

In the simplest suspension designs, this is a single dimension. There are many passenger car suspensions, however, that employ primary and secondary suspensions whose springs are not in vertical alignment. This is especially common where air springs are located between a floating bolster and the vehicle body, while mechanical springs are located at, or in line with, the journal box.

5. Side bearing clearance (if applicable)

Side bearing clearance will allow the vehicle body to roll freely until contact is made, at which point the load on the springs on that side of the vehicle will start to increase. With constant-contact side bearings, there is no clearance, so any body roll is translated immediately into increased spring loading.

6. Lateral distance between center of side bearing and longitudinal centerline of vehicle (if applicable):

The lateral distance between the center of the side bearing and the centerline of the vehicle, together with the side bearing clearance, determines the angle through which the vehicle body can roll before side bearing contact occurs.

> **NOTE:** These parameters provide variables for a typical truck design. Other variables may need to be considered based on the specific truck design being employed (e.g., anti-roll bar). The truck manufacturer should be consulted to ensure that all relevant variables are considered.

Although the parameters described above and possibly other parameters as applicable for each truck type, together with the amount of elevation, are sufficient to calculate body lean on elevated track, the calculation is not simple, because it involves several equations and an iterative solution process. A more practical alternative is to conduct a static lean test of an actual vehicle.

The AREMA *Manual for Railway Engineering*, Chapter 28, Part 3, Section 3.1, contains a procedure for conducting such a test. The AREMA procedure determines the combined lateral displacement caused both by leaning and by lateral displacement due to tolerances and wear. Wear limits of the suspension components should be taken into consideration when evaluating the results of the lean test.

Because of the cost and difficulty involved in preparing a car for such testing, it is recommended that the relative lateral shift of the various test car components mentioned in sections 2.3.2.1 and 2.3.2.2 should be measured during the test, and these shifts should be subtracted from the test results so that the test results represent only the lateral displacement resulting from vehicle lean. Since the potential lateral displacements due to design tolerances and wear were already calculated in sections 2.3.2.1 and 2.3.2.2, they can be added in as needed.

If it is not feasible to obtain lean data from an equipment lean test, the data must be estimated for various levels of elevation by means of the series of calculations described in Section 2.3.2.3 based on anticipated suspension characteristics. If agreed between the railroad and contractor, it shall also be acceptable to utilize validated multibody simulations in lieu of conducting an actual lean test. If a simulation is to be used, it is critical that adequate documentation be provided to establish credibility in the modeling methodology and the ability of the model to produce realistic results. Validation of models shall be completed utilizing results from previously conducted lean tests on the vehicle design in question.

- ✓ **Develop static lean data for various amounts of elevation, either by calculation, by simulation or by conducting a static lean test as described above. If a static lean test is conducted, the side bearings should be adjusted to their maximum permissible clearance, and the total lateral displacement of the body should be measured for each case.**

- ✓ **If a static lean test is conducted, adjust the results by subtracting relative lateral displacements (corrected for lean angle) of the various components itemized in sections 2.3.2.1 and 2.3.2.2 to obtain lateral displacements due to lean only.**

- ✓ **Whether the static lean data are developed by calculation, simulation or test, add to the lean-induced lateral displacements the maximum lateral displacements (adjusted for lean angle) due to design tolerances and wear as determined in sections 2.3.2.1 and 2.3.2.2. Plot data in a graph similar to Figure 28-3-3 in the AREMA *Manual for Railway Engineering*, Chapter 28, Part 3.**

> **NOTE:** The above procedure adds the maximum component displacements to the lateral lean-induced displacement for all levels of elevation. In reality, the component displacements will be somewhat affected by the amount of elevation. Therefore, a straight line drawn through all the plotted points will probably not pass through the zero of coordinates. It is recommended that a straight line be drawn through the zero of coordinates from the point representing the highest test elevation.

This graph presents static lean data. The next step is to determine the lean of a moving vehicle. In order to do this, the unbalanced elevation must be calculated at each obstruction located on a curve.

The first step in doing this is to calculate the equilibrium elevation corresponding to each obstruction using **Formula 3**.

> **NOTE:** The equilibrium elevation is the elevation at a given speed where the resultant of the vehicle weight and centrifugal force is perpendicular to the plane of the track.

> **CAUTION:** Use only English units in formulas in this recommended practice.

$$E_r = 0.0007V^2D \tag{3}$$

where:
E_r = elevation required for equilibrium (inches)
V = vehicle speed (mph)
D = curvature (degrees)

The next step is to calculate the unbalanced elevation corresponding to each of these obstructions using **Formula 4**:

$$E_u = E_r - E_a \tag{4}$$

where:
E_u = unbalanced elevation
E_a = actual elevation

The lateral displacement corresponding to the unbalanced elevation at each obstruction located on a curve can then be determined from the graph plotted as described above.

- ✓ **Determine equilibrium elevation corresponding to each wayside obstruction located on a curve as explained above.**

- ✓ **Determine unbalanced elevation corresponding to each wayside obstruction located on a curve as explained above.**

- ✓ **Determine lateral displacement of vehicle body at the location of each wayside obstruction on a curve using graph plotted above.**

The other suspension characteristics that need to be examined are the spring deflection limits. It is necessary to refer to the truck manufacturer's drawings to determine these limits.

The total downward spring deflection possible from the normal empty-car position when under maximum load (including full deflated air springs, if used) will affect the location of appurtenances on the underside of the body, because these appurtenances must comply with the minimum clearance specified above the top of rail (see Section 2.3.1.3).

The total upward spring deflection possible from the normal empty-car position until the springs reach their limit of travel can be assumed to represent the extreme condition for upward bounce of the body. Greater upward movement of the body would result in center plate lift, which cannot be tolerated, and bounce can be limited by controlling speed.

- ✓ **Determine upper and lower limits on vertical body motion as determined by spring deflection limits.**

2.4 Track considerations

2.4.1 Rail wear

Wear of the inside of the rail head translates directly into increased track gauge. Track gauge is one of the factors considered by the Federal Railroad Administration in determining track class; track class, in turn, determines the maximum speed at which trains are allowed to operate. If wear on the inside of the rail head $\mathbf{W_2}$ is assumed to be one-half of the increase in track gauge, then it is determined by **Formula 5**:

CAUTION: Use only English units in formulas in this recommended practice.

$$\mathbf{W_2 = 0.5(g_m - g_t)} \qquad (5)$$

where: $\mathbf{g_m}$ = maximum track gauge for class of track over which trains are operated
$\mathbf{g_t}$ = standard track gauge at a point below top of rail = 56.5 in.

The values of $\mathbf{g_m}$ and $\mathbf{W_2}$ for various FRA classes of track over which passenger trains are likely to operate are shown in **Table 2**.

TABLE 2
Maximum Track Gauge and Rail Head Wear by FRA Track Class

FRA Track Class	Maximum Passenger Train Speed	Maximum Track Gauge (g_m)	Rail Head Wear (W_2)
3	60 mph	57.75 in.	0.625 in.
4	80 mph	57.50 in.	0.50 in.
5	90 mph	57.50 in.	0.50 in.
6	110 mph	57.25 in.	0.375 in.

2.4.2 Track irregularities

Track irregularities are difficult to take into account in a meaningful way, because statically measured irregularities usually change under dynamic load. Even if these irregularities could be defined precisely, their effect on vehicle dynamic behavior varies as a function of all the suspension characteristics defined in Section 2.3.2.3, plus vehicle speed and distance between truck centers.

There is a simpler way to approximate the effect of track irregularities. Figure 28-3-4 in the AREMA *Manual for Railway Engineering*, Chapter 28, Part 3, Section 3.1, presents adjustment factors to be applied to the lateral displacements determined from the graph plotted in Section 2.3.2.3 to account for the dynamic behavior of passenger cars over track irregularities. Figure 28-3-4 provides these adjustment factors for all speeds up to approximately 93 mph (151.8 km/hr) based on actual measurements of the lean of eight passenger cars with different types of trucks when operated over high-speed track.

- ✓ **Determine adjustment factors from Figure 28-3-4 in the AREMA *Manual for Railway Engineering*, Chapter 28, Part 3, to compensate for the dynamic behavior of equipment operating over track irregularities at the various authorized train speeds.**

- ✓ **Apply these factors to the lateral displacements determined in Section 2.3.2.3.**

2.5 Combining information on fixed obstructions, legal requirements, equipment characteristics and track irregularities into a single diagram

Fixed obstructions along the track were identified and plotted in Section 2.1. Legal clearance requirements were identified in Section 2.2 and were incorporated into the diagram developed in Section 2.1.

Wherever a fixed obstruction occurs on a curve, it can be converted into an equivalent obstruction along tangent track by moving it toward the centerline of the track by an amount equal to the offset of the longitudinal centerline of the vehicle from the track centerline.

If the fixed obstruction is on the inside of the curve, it should be moved toward the centerline of the track by an amount equal to the offset of the longitudinal centerline of the vehicle from the track centerline at a point midway between the truck centers. This offset can be calculated using **Formula 6**:

> **CAUTION:** Use only English units in formulas in this recommended practice.

$$\mathbf{L = R - (R^2 - T^2 / 4)^{1/2}} \qquad \textbf{(6)}$$

where:
- **L** = offset of vehicle centerline from track centerline at middle of vehicle
- **R** = radius of curve
- **T** = distance between vehicle truck centers on which clearance diagram is to be based (see Section 2.3.1.1)

> **NOTE:** If only the curvature in degrees is known, then **R** (in feet) may be calculated using the formula **R = 5729.65/C** where C is the curvature in degrees.

If the fixed obstruction is on the outside of the curve, it should be moved toward the centerline of the track by an amount equal to the offset of the longitudinal centerline of the vehicle from the track centerline at the end of the vehicle. This offset can be calculated using **Formula 7**:

$$L' = (R^2 - T^2 / 4)^{1/2} - (R^2 - T'^2 / 4)^{1/2} \quad (7)$$

where:
L′ = offset of vehicle centerline from track centerline at end of vehicle
R = radius of curve
T = distance between vehicle truck centers on which clearance diagram is to be based (see Section 2.3.1.1.)
T′ = overall length of vehicle body (see Section 2.3.1.1.)

> **NOTE:** Strictly speaking, the offset at the end should be calculated in a radial direction. However, the mathematics are more complex, the difference is very small for typical vehicle lengths and track curvature, and the slight error is in a conservative direction. For example, for an 85 ft car with a distance between track centers of 59 ft, 6 in., the difference in the results obtained by the simplified method and the more rigorous method is approximately ¼ in.

The logical next step is to determine the minimum clearance desired between the equipment and the adjusted obstructions in the composite diagram under the most severe conditions of body movement. The composite diagram should then be further modified by moving all fixed obstructions on either side of the track laterally toward the track and all fixed obstructions above the track downward by the amount of minimum clearance desired. At this point the modified composite diagram represents the envelope through which the equipment should be able to operate without violation.

✓ **Modify the composite diagram developed in sections 2.1 and 2.2 by converting lateral obstructions on curves to equivalent tangent-track obstructions and moving all charted obstructions inward by the amount chosen as the minimum clearance under worst-case conditions.**

This modified composite diagram can now be used as the foundation for developing the equipment clearance diagram based on the various factors discussed in sections 2.3 and 2.4. Each of these factors is discussed below.

1. Truck centers (Section 2.3.1.1)

At this point, the truck center length has already been taken into account, because it was used when modifying the composite diagram to convert right-of-way obstructions on curves into equivalent obstructions on tangent track.

2. Extreme width (Section 2.3.1.2)

Two vertical lines tentatively representing the extreme equipment width should be drawn on the composite diagram.

> **NOTE:** 10 ft, 6 in., (3.20 m) is the recommended maximum dimension under any circumstances.

3. Clearance above top of rail (Section 2.3.1.3)

A horizontal line representing the minimum clearance above the top of the rail should be drawn on the composite diagram at the proper height.

> **NOTE:** The recommended dimension is 2.5 in. (6.35 cm) (per 49 CFR §229.71).

4. Design tolerances (Section 2.3.2.1) and wear limits (Section 2.3.2.2)

The two vertical lines representing the extreme equipment width must be relocated to account for the lateral design tolerances and the maximum permissible lateral wear of both track and equipment suspension components. Each vertical line must be moved outward by an amount equal to $\mathbf{T_{tot}} + \mathbf{W_{tot}}$. ($\mathbf{T_{tot}}$ was calculated in Section 2.3.2.1, and $\mathbf{W_{tot}}$ was calculated in Section 2.3.2.2.)

5. Suspension characteristics (Section 2.3.2.3) and track irregularities (Section 2.4.2)

In order to compensate for vertical bounce of the vehicle, the adjusted locations of fixed obstructions over the track that were previously plotted should be moved downward by the amount of the maximum upward spring deflection determined in Section 2.3.2.3.

The vertical lines drawn on the composite diagram in paragraph 4 above should be rotated about the body pivot point (usually the center plate) to reflect the dynamic lean at each wayside obstruction located on a curve. This is done by referring to the elevation and authorized train speed corresponding to each obstruction and using the corresponding dynamic lean data from the graph plotted in sections 2.3.2.3 and 2.4.

The lateral body displacement due to authorized speed in excess of equilibrium speed was determined in Section 2.3.2.3 at each wayside obstruction located on the outside of a curve. These displacements must be adjusted by the appropriate dynamic allowance factors from Table 4 in the AREMA *Manual for Railway Engineering*, Chapter 28, Part 3. The vertical lines drawn on the composite diagram in paragraph 4 above should then be rotated about the body pivot point (usually the center plate) to reflect the outward lean at each of these locations. This is done by referring to the authorized maximum train speed corresponding to each obstruction and applying the corresponding adjustment factor.

✓ **Refine the composite diagram by following the steps in paragraphs 2–5 above.**

At this point, the composite diagram contains the following:

1. An envelope defining the space through which the equipment should operate without violation.
2. A line parallel to the plane of the track defining the minimum clearance above the top of the rails.
3. Two lines representing the sides of the vehicle under the worst conditions of lean and lateral displacement if the vehicle is constructed to the extreme width selected in Section 2.3.1.2.

✓ **Define the extreme vehicle height as explained above.**

The extreme height of the vehicle is defined based on paragraphs 1 and 3 immediately above. It is not necessary that this extreme height be achievable over the full width of the vehicle; in fact, it usually is not. Passenger equipment is commonly constructed with a convex roof, in which case the vehicle body approaches the extreme height only at the center.

✓ **Plot the limits of vehicle width throughout its height as a function of the predefined maximum width (Section 2.3.1.2) and the clearance envelope through which the vehicle must operate.**

Since the vehicle body must remain within the envelope defined in paragraph 1 above, the body width must be reduced wherever the two lines in paragraph 3 above cross over this envelope. This can be done in steps, or the limiting equipment outline can be tapered.

✓ **Complete the limiting equipment outline as described above.**

The shape of the limiting equipment outline connecting the sides and the top must be determined. Depending on the shape of the envelope, it may be sloped or curved.

- ✓ **Examine the limiting equipment outline thoroughly to determine whether it is realistic or needs to be modified in some way. If modifications are needed, follow any or all of the three steps outlined below to arrive at the final outline (or equipment clearance diagram).**

This may be done by comparing it with existing passenger clearance diagrams such as AAR Standard S-035 or the Amtrak diagram for comparable (single-level or bilevel) equipment, as well as by determining whether equipment already owned or contemplated for acquisition by the passenger railroad will comply with it. If this outline is acceptable, it may be adopted as the passenger railroad's equipment clearance diagram. If there are portions of the outline that are too restrictive, there are three principal possibilities for reducing or eliminating these restrictions. They are discussed in priority order below:

1. The obstructions responsible for these restrictions should be identified, and the possibility of eliminating them should be evaluated. The outline should be adjusted to reflect the elimination of any limiting obstructions.
2. The characteristics of the vehicle suspension system should be analyzed to determine whether the desired suspension performance can still be achieved with a design that reduces body roll sufficiently to eliminate the problem. If so, the change in displacement due to body lean should be determined, and the outline should be adjusted to reflect this.
3. The authorized train speed in the vicinity of the obstruction should be examined to see if a speed reduction would reduce the potential body displacement sufficiently to eliminate the problem. As in paragraph 2 above, the change in displacement due to body lean should be determined, and the outline should be adjusted to reflect this. Operating considerations, of course, would also enter into any decision on speed reduction.

- ✓ **Evaluate vehicles constructed to the limiting equipment outline to ensure that there is no conflict between passing trains on the most critical curves in multiple track territory.**

Use a clearance diagram development tool to evaluate the overhang on multiple-track curves of passing vehicles designed to the limiting equipment outline developed. The end overhang of the vehicle on the inner track and the center overhang of the vehicle on the outer track need to be compared with the track center distance to ensure adequate clearance between passing trains.

If the clearance is not obviously adequate, a more careful examination needs to be made. The most critical condition on a curve is a standing train on the outer track and a train operating at maximum authorized speed on the inner track.

If any conflict exists, the limiting equipment outline must be modified. Alternatively, operating restrictions could be imposed or the distance between track centers could be increased at the critical locations.

- ✓ **If the particular passenger railroad's equipment is to be operated only on its own tracks, then the equipment clearance diagram is complete. If it is to be operated on another railroad's tracks, go to Section 3.**

3. Clearance diagram for track owned by another railroad

When a passenger railroad's trains are operated on another railroad's tracks, questions relating to clearances are much simpler to resolve, because the railroad owning the tracks will already have investigated its clearances.

- ✓ **Obtain a clearance diagram from the railroad involved.**

The railroad over which the equipment will be operated will usually not be able to supply a composite diagram of right-of-way restrictions for the line(s) involved as described in Section 2.1. However, the railroad's clearance engineer should be asked to supply a clearance diagram showing the maximum acceptable equipment dimensions for operation over these lines. Vehicle body displacement due to design tolerances, wear and spring deflection is typically taken into account to arrive at the maximum permissible dimensions for inclusion in such diagrams.

- ✓ **Review the railroad clearance diagram for limitations that may present problems.**

Height restrictions will be identical for all equipment on a given route. Equipment width restrictions at any height may be evaluated with a clearance diagram development tool of choice.

- ✓ **Review problem areas with railroad's clearance engineer.**

Certain clearance limitations may sometimes be eliminated at little expense. This may be preferable to constructing new equipment to dimensions that are less than ideal.

- ✓ **If clearance diagram changes are agreed upon with the railroad, obtain a revised clearance diagram.**

- ✓ **Evaluate vehicles constructed to the limiting equipment outline to ensure that there is no conflict between passing trains on the most critical curves in multiple track territory.**

Use a clearance diagram development tool of choice to evaluate the overhang on multiple track curves of passing vehicles designed to the limiting equipment outline developed. The overhang of the vehicle on the inner track and the center overhang of the vehicle on the outer track need to be compared with the track center distance to ensure adequate clearance between passing trains.

If the clearance is not obviously adequate, a more careful examination needs to be made. The most critical condition on a curve is a standing train on the outer track and a train operating at maximum authorized speed on the inner track.

If any conflict exists, the limiting equipment outline must be modified. Alternatively, operating restrictions could be imposed or the distance between track centers could be increased at critical locations.

- ✓ **If the particular passenger railroad's equipment is to be operated only on another railroad's tracks, the equipment clearance diagram is complete. If it is to be operated both on its own and another railroad's tracks, go to Section 4.**

4. Combined clearance diagram for both track owned by the passenger railroad and track owned by another railroad

- ✓ **Perform a detailed comparison of the equipment clearance diagram developed in Section 2 and the clearance diagram obtained from the other railroad in Section 3.**

- ✓ **Reconcile the two clearance diagrams to arrive at a final equipment clearance diagram for the passenger railroad.**

If the other railroad's clearance diagram is more restrictive in any respect, that restriction should be added to the passenger railroad's own clearance diagram unless further discussion with the other railroad's clearance engineer determines that this restriction can be lifted.

Related APTA standards

APTA PR-E-RP-004-98, "Gap and Creepage Distance"

References

American Railway Engineering and Maintenance-of-Way Association (formerly American Railway Engineering Association), *Manual for Railway Engineering* Chapter 28 ("Clearances") and Chapter 5 ("Elevations and Speeds for Curves").

> **NOTE:** The organization formerly known as the American Railway Engineering Association (AREA) became the American Railway Engineering and Maintenance-of-Way Association (AREMA) on January 1, 1998.

Association of American Railroads, *Manual of Standards and Recommended Practices*.

- Standard S-2026-88, "Equipment Diagram for Unrestricted Interchange Service, Plate B"; Section C, Part I (latest revision).
- Standard S-2028-91, "Equipment Diagram for Limited Interchange Service, Plate C"; Section C, Part I (latest revision).
- Standard S-2031-74, "Equipment Diagram for Limited Interchange Service, Plate E; Section C, Part I (latest revision).
- Standard S-2032-74, Equipment Diagram for Limited Interchange Service, Plate F"; Section C, Part I (latest revision).
- Standard S-2040-93, 2032-74, "Equipment Diagram for Double-Stack Container Cars Limited Interchange Service, Plate HF"; Section C, Part I (latest revision).
- Standard S-2040-93, "Equipment Diagram for Double-Stack Container Cars, Plate H"; Section C, Part I (latest revision).
- Standard S-035-53, "Passenger Equipment Diagram Unrestricted for Interchange Service"; Section A (obsolete), Part III (1953), p. A-III-12.

The Economic Theory of the Location of Railways, sixth edition, corrected, page 266; A. M. Wellington; John Wiley & Sons, Inc.; 1914.

Definitions

Amtrak: National Railroad Passenger Corporation.

c.g.: Height of center of gravity of vehicle above top of rail.

clearance diagram: As used in this document, this term means a cross-sectional drawing showing the limiting dimensions to which railroad equipment may be constructed. It is normally qualified in two ways. First, it specifies that the overhang of the equipment on a curve of specified radius may not exceed the overhang on the same curve of a piece of equipment with a specified length between truck centers and built to the full diagram width. Second, it usually specifies some body deflection conditions under which the requirements of the diagram must still be met.

> **NOTE:** Strictly speaking, the term "clearance diagram" refers to a diagram based on fixed obstructions along the right-of-way that must be cleared by passing trains; this is the sense in which the term is used by AREMA. The diagram whose development is described in this recommended practice is called an "equipment diagram" by AREMA. It would be described more completely as an "equipment construction limit diagram," but this term is cumbersome. Thus, this recommended practice follows the common practice of referring to this diagram as a "clearance diagram."

curvature: The severity of a track curve expressed in degrees and minutes.

equipment: Locomotives and cars.

right-of-way: The land on which the railroad track and associated structures (bridges, tunnels, signals, platforms, etc.) are located.

elevation: The difference in height between the outside and inside rails on a curve to compensate (at least partially) for the centrifugal force of a train going around the curve.

spring rate: The compressive force on a spring per unit of deflection (usually expressed in pounds per inch). Some types of springs (e.g., conventional steel coil springs) have a relatively constant spring rate throughout their normal range of deflection. Others (e.g., inclined rubber chevron springs) have a spring rate that increases with deflection.

tangent: Straight; without curvature.

Abbreviations and acronyms

AAR	Association of American Railroads
AREMA	American Railway Engineering and Maintenance-of-Way Association
c.g.	center of gravity
FRA	Federal Railroad Administration

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	CEO Approval	Policy & Planning Approval	Publish Date
First published	—	—	—	March 26, 1998	March 17, 1999
First revision	—	—	—	—	March 22, 2004
Second revision	Dec. 12, 2023	Feb. 1, 2024	Feb. 18, 2024	March 6, 2024	April 24, 2024

Appendix A: Sample additional considerations (bolstered truck)

The following are examples of additional parameters to be considered for a typical bolstered truck.

Lateral design parameters

1. Lateral tolerance between wheels and rails

Refer to Section 2.3.2.1 for calculation method of $\mathbf{T_1}$.

2. Clearance between center plate and center bowl

The manufacturers' drawings will show the exterior diameter of the center plate and the interior diameter of the center bowl. The maximum lateral movement $\mathbf{T_2}$ possible for a new center plate centered in the center bowl is shown in **Formula 8**:

> **CAUTION:** Use only English units in formulas in this recommended practice.

$$\mathbf{T_2 = 0.5(d_b - d_p)} \quad (8)$$

where: d_b = center bowl diameter
d_p = center plate diameter

3. Relative motion between truck bolster and frame

On trucks where the bolster is not part of the truck frame and is supported by swing hangers, relative lateral movement occurs between the bolster and frame. The manufacturer's drawings must be consulted to determine the maximum lateral movement $\mathbf{T_3}$ of the bolster from its neutral position.

> **NOTE:** This item does not apply if the truck bolster is an integral part of the truck frame.

4. Relative motion between floating bolster and body

Where a floating bolster is used between the truck and the body (to accommodate air springs or a combination of air and coil springs), the manufacturer's drawings must be consulted to determine the maximum lateral movement $\mathbf{T_4}$ of the floating bolster from its neutral (centered) position.

> **NOTE:** This item does not apply if there is no floating bolster.

5. Relative motion of roller bearing with respect to adapter and truck frame

Manufacturers' drawings for the roller bearing, adapter (journal box, swing arm, etc.), and truck frame must be consulted to determine the maximum possible lateral movement between the roller bearing and the adapter and between the adapter and the truck frame. The maximum lateral movement $\mathbf{T_5}$ between the truck frame and the roller bearing in its neutral (centered) position is then determined by **Formula 9**:

> **CAUTION:** Use only English units in formulas in this recommended practice.

$$\mathbf{T_5 = 0.5(t_{ba} + t_{af}) + t_{blat}} \quad (9)$$

where: $\mathbf{t_{ba}}$ = maximum design lateral movement between roller bearing and adapter
$\mathbf{t_{af}}$ = maximum design lateral movement between adapter and truck frame
$\mathbf{t_{blat}}$ = maximum application lateral movement in the bearing (0.015 in. maximum per AAR manual)

6. Side bearing clearance

If the side bearings are not of the constant-contact type, there is a nominal design clearance between the body-side bearing and the truck-side bearing. Rocking of the body on the center plates will allow the body- and truck-side bearings to contact. Since the static lean test described in Section 2.3.2.3 includes the effect of side bearing clearance, it need not be calculated separately.

Determine the maximum total lateral movement of the body with respect to the track resulting from design tolerances by the formula $\mathbf{T_{tot} = T_1 + T_2 + T_3 + T_4 + T_5}$ using the values determined in paragraphs 1, 2, 3, 4 and 5 above.

Wear limits

1. Center plates and center bowls

Wear limits for center plates and center bowls are at the discretion of the individual passenger railroad based on carbuilder guidance and recommendations. The AAR limit for the difference between the center bowl diameter and the center plate diameter on freight cars is 1 in. (2.54 cm). It is recommended that this limit not be exceeded on passenger cars.

The maximum lateral displacement $\mathbf{W_3}$ of the car body resulting from wear of the center plate and center bowl is determined by **Formula 10**:

CAUTION: Use only English units in formulas in this recommended practice.

$$\mathbf{W_3 = 0.5d_{\Delta} - T_2} \qquad (10)$$

where: $\mathbf{d_{\Delta}}$ = maximum permissible difference in diameters of center plate and center bowl

$\mathbf{T_2}$ = maximum lateral movement of new center plate centered in center bowl (see “Clearance between center plate and center bowl” above).

Appendix B: Electrical gap and clearance considerations

Clearance diagrams are typically developed to analyze potential physical restrictions of operating equipment on certain track. Clearance diagrams can also be used as a starting point for ensuring that the vehicle will meet the required electrical gaps and creepage distances with respect to the wayside installations. Refer to APTA PR-E-RP-004-98 for the minimum gaps and creepage distances.

