Form 36

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Part 2: Rolling stock gauge

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**Introduction**

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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| 1 | 2 | (3) | 4 | 5 | (6) | 7 |
|---|---|---|---|---|---|---|
| **MB** | Clause No./ Subclause No./Annex **(e.g. 3.1)** | Paragraph/Figure/ Table/Note | **Type of comment** | **Commend (justification for change) by the MB** | **Proposed change by the MB** | **Secretariat observations on each comment submitted** |
| | 3.1 | Definition 1 | ed | Definition is ambiguous and needs clarifying. | Amend to read '...so that the mains connector to which no connection...' | |
| | 6.4 | Paragraph 2 | te | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer. | |

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EUROPÄISCHE NORM

# DRAFT
# prEN 15273-2

March 2023

ICS 45.020; 45.060.01

Will supersede EN 15273-2:2013+A1:2016

English Version

# Railway applications - Gauges - Part 2: Rolling Stock

Applications ferroviaires - Gabarits - Partie 2 : Matériel roulant

Bahnanwendungen - Begrenzungslinien - Teil 2: Fahrzeuge

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 256.

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## European foreword

This document (prEN 15273-2:2023) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 15273-2:2013+A1:2016.

This document is one of the series prEN 15273, *Railway applications — Gauges* as listed below:

— prEN 15273-1: *General-common rules for Rolling stock and Infrastructure* gives the general explanations of gauging and defines the sharing of the space between rolling stock and infrastructure;

— prEN 15273-2: *Rolling stock* gives the rules for dimensioning vehicles;

— prEN 15273-3: *Infrastructure* gives the rules for positioning the infrastructure;

— prEN 15273-4: *Catalogue of defined gauges* includes a non-exhaustive list of reference profiles and parameters to be used by infrastructure and rolling stock;

— prCEN/TR 15273-5: *Background, explanation and worked examples*.

In comparison with the previous edition, the following technical modifications have been made:

— the series was fully restructured, from three parts to five parts;

— Clause 3 and Clause 4 now refer to prEN 15273-1:2023 where all terms and symbols are defined;

— modification of the whole Clause 5;

— reordering of all specifics rules of defined kinematic gauge inside the Annexes A to P by moving to the normative Annex A;

— addition of new rules in Annex A about the wheel-zone;

— restructured A.3.13 and A.3.16 into two Annexes, normative Annex B for passive tilting vehicle and informative Annex C for active tilting vehicle;

— addition of a new normative Annex D about the graphical method use for Defined kinematic gauge;

— for defined kinematic gauge, removal of all reference profile inside the prEN 15273-2:2023 replace in Normative Annex E by tables with the links with prEN 15273-4:2023 to define the reference profile, basic data and lateral projections;

— for defined static gauge, removal of all reference profile inside the prEN 15273-2:2023 replace in Normative Annex G by tables with the links with prEN 15273-4:2023 to define the reference profile, basic data and lateral projections;

— regrouping all particular rules for German, Belgian and pantograph gauges in normative Annex E;



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— reordering all specifics rules of defined static gauge inside the Annexes A to P by moving to the normative Annex F;

— for all define gauges (static, kinematic and dynamic), removal of all formulae for calculating specific lateral reductions and replacement by generic formulae in each normative Annexes A, F and K;

— removal of specific Annex K defined static gauges OSJD;

— removal of normative Annex Q Vehicle widening depending on the available spaces of the infrastructure;

— content of normative Annex R Static and kinematic gauges: list of documents for a vehicle gauge conformance certification moved to normative Annex N list of documents for rolling stock gauge assessment applicable for defined kinematic, static and dynamic gauges;

— addition of absolute gauging process and comparative process in normative Annex M.

This document has been prepared under a Standardization Request given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s) / Regulation(s).

For relationship with EU Directive(s) / Regulation(s), see informative Annex ZA, which is an integral part of this document.

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# Introduction

The aim of this document is to define the rules for the calculation and verification of the dimensions of rolling stock and infrastructure from a gauging perspective.

This document describes gauging processes taking into account the relative movements between rolling stock and infrastructure as well as the necessary margins or clearances.

This part of the series prEN 15273 covers rolling stock gauges and is used in conjunction with the following parts:

— *Part 1: General-common rules for Rolling stock and Infrastructure*;

— *Part 3*; Infrastructure;

— *Part 4: Catalogue of defined gauges*;

— *Part 5: Background, explanation and worked examples*.



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# 1 Scope

This document is applicable to new vehicle designs, to modifications to existing vehicles and for checking existing vehicles to be used on another route or network.

This document contains:

— the rules for rolling stock for all defined gauges;

— the swept envelope calculation process used for defined dynamic gauges, absolute and comparative process;

— the list of documents required to assess vehicle conformity to this standard.

This document is applicable to heavy rail vehicles using various track gauges. Other vehicles are outside the scope of this document, but the rules may be applied to them.

This document is not applicable to the gauges “S” and “T” for track gauge 1 520 mm.

# 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 14363:2016+A2:2022, *Railway applications - Testing and Simulation for the acceptance of running characteristics of railway vehicles - Running Behaviour and stationary tests*

prEN 15273-1:2023, *Railway applications - Gauges - Part 1: General-Common rules for Rolling stock and Infrastructure*

prEN 15273-3:2023, *Railway applications - Gauges - Part 3: Infrastructure*

prEN 15273-4:2023, *Railway Applications - Gauges - Part 4: Catalogue of defined gauges*

prCEN/TR 15273-5:2023, *Railway applications - Gauges - Part 5: Background, explanation and worked examples*

EN 15663:2017+A1:2018, *Railway applications - Vehicle reference masses*

EN 50119:2020, *Railway applications - Fixed installations - Electric traction overhead contact lines*

EN 50215:2009, *Railway applications - Rolling stock - Testing of rolling stock on completion of construction and before entry into service*

EN 50367:2020, *Railway applications - Fixed installations and rolling stock - Criteria to achieve technical compatibility between pantographs and overhead contact line*[1]

[1] Document impacted by A1:2022.



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# 3 Terms and definitions

For the purposes of this document, the terms and definitions given in prEN 15273-1:2023 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org

# 4 Symbols and abbreviations

For the purposes of this document, the symbols and abbreviations given in prEN 15273-1:2023 apply.

# 5 Gauges and gauging processes

## 5.1 General principles for all defined gauges

a) It is mandatory to respect the association specified in each gauge between its reference profile and its associated rules.

b) The defined gauge calculation shall be based upon the assumption that all the vehicle characteristics that influence the gauge are maintained throughout the operational life of the vehicle. These characteristics shall be stated in the maintenance documentation, including the factors influencing displacements and their limiting or maximum values (e.g. limits of wear on suspension components).

a) Wear limits of all parts, equipment and systems influencing movements of the vehicle shall be included in the documents provided by the Railway Undertaking for approving the use of the vehicle.

c) For consistency, the maximum construction gauge is drawn with the vehicle in loading condition “dead mass” as defined by EN 15663:2017+A1:2018, nevertheless calculations are made taking into account all loading conditions.

d) If the vehicle does not fully meet the requirements of the defined gauge, in exceptional cases it may be approved for operation with derogation. It is not then compatible with all the Infrastructures cleared for the gauge considered.

## 5.2 Defined static and kinematic gauges

The calculation methods applied for the defined gauges are based on reference profile and their associated rules.

The static and kinematic gauges take into account the maximum value of each displacement.

The static method can be used up to a limit value of the flexibility coefficient ( $s_{lim}$ ).

The kinematic method can be used regardless of the value of the flexibility coefficient.



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## 5.3 Dynamic methods

### 5.3.1 General principles

The vehicle simulation model shall be validated by calculations, by comparisons with other vehicles, by testing or by other appropriate means commensurate with the level of risk, complexity and innovation in the vehicle design. The method of validation will depend on the process being followed.

### 5.3.2 Dynamic method based on defined gauges

The vehicle shall not exceed a certain reference profile including the curve radii dependent projections added under specified conditions. Multiple vehicle swept envelopes shall be calculated by defining the maximum vehicle space to be occupied under normal service and certain failure conditions for each curve radius. The dynamic movement may be calculated either by use of formulae or by simulations. This envelope shall remain within the dynamic reference profile including the adding of curve radii dependent projections on routes where the vehicle is required to operate.

### 5.3.3 Absolute gauging process

The absolute gauging process requires calculation of clearance between the swept envelope of the vehicle and the infrastructure at every location along a route. The local conditions (eg track curvature, installed cant, line speed and track fixity) are used to determine the swept envelope of the vehicle on the effective track position. Acceptable clearances between the vehicle swept envelope on the effective track position and all infrastructure on a route are required to achieve gauging compatibility.

### 5.3.4 Comparative gauging process

The comparative gauging process relies on existing vehicles known as comparator vehicles operating safely on a route. Where all swept envelopes of the candidate vehicle are within the swept envelopes of a comparator vehicle, or vehicles, having been assessed as having gauging compatibility with the section of track, then gauging compatibility shall be deemed to be achieved. The swept envelopes of both comparator and candidate vehicles are calculated on a virtual route by use of simulations.

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# Annex A
(normative)

# Defined kinematic gauges — common rules

## A.1 General rules

### A.1.1 Requirements for use of defined kinematic gauges

The following requirements and considerations apply to defined kinematic gauges:

a) The formulae specified for each defined kinematic gauge shall be applied by introducing all the "worst case" parameters, i.e. with their maximum values (e.g. clearances, lateral and vertical displacements etc.) while taking realistic combinations of the parameters into account.

b) If, as a derogation from the above point, a vehicle is designed using one or several parameters with their optimized value (a calculated value, or one encountered during operation), the gauge documents shall be submitted to the body responsible for conformity assessment in the form of simulation analysis reports, test reports, risk analyses etc. In this case, the whole range of situations (e.g. maximum operating speed, maximum cant deficiency, dynamic displacements, load states etc.) shall be taken into account. It should be noted that this procedure could result in a vehicle being specified that would not be compatible with all infrastructure even if it fits the gauge of the same designation.

c) Defined kinematic gauges apply also to open wagons and their loads. In this case, the flexibility coefficient of the load itself shall be taken into account, adding it to the flexibility of the suspension of the wagon itself.

   In these conditions, the whole set "wagon+load" can be regarded as a current type of wagon. Wagons loaded with containers and swap bodies (transported on carrier wagons equipped with load fixing devices) and semi-trailers (transported on pocket wagons) are examples of the above application.

d) Before new vehicles enter service the flexibility coefficient shall be verified by measurement according to EN 14363:2016+A2:2022 (method 1 or method 2). For cases, in which the spatial distribution of the payload cannot be reproduced correctly in test conditions (e.g. centres of gravity of seated and standing passengers), the assessment of the flexibility coefficient s via computer simulations based on a validated vehicle model shall be considered sufficient.

e) The calculation and the measurement of the flexibility coefficient s can result in different values (e.g. because of different wagon loadings). In any case, the choice of the value of s retained for gauge calculation according to prEN 15273-2:2023 shall be clearly justified in the technical documents accompanying the vehicle (See Annex N).

f) Defined kinematic gauges can be used to size tilting vehicles.

   Annex B is considered normative since passive tilting is based on the basic principle of having the rotation centre above the centre of gravity, regardless of the technology used in the



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vehicle. Therefore, the formulae developed in Annex B are not expected to be influenced by different technologies used in different passive tilting vehicles.

However, active tilting is dependent on the technology used to force the rotation, and therefore, formulae developed in Annex C may need to be adapted. Therefore, the general formulae in Annex C, based on a general principle used in the industry for this kind of vehicles (actuators located between the bogie frame and the carbody), can only be considered informative.

The compatibility of passive and active tilting trains with the corresponding infrastructure shall be subject to a specific procedure for permission to operate by the Infrastructure Managers concerned.

g) Concerning the verification of pantographs mounted on the tilting vehicles or subject to $I = Ip > Ic$, three cases are dealt with in this standard:

— pantographs that are not part of the tilting mechanism.

These can include pantographs mounted on non-tilting elements of the tilting body (for example bogies) or pantographs mounted on non–tilting bodies but subject to $I = Ip > Ic$. This is included in Annex B because it is related to a non-active system;

— pantographs that are attached to the tilting body with a counter rotation system.

These are pantographs mounted on tilting vehicles equipped with a counter rotational device. This is included in Annex C;

— pantographs with an in-built re-centering system.

There are pantographs equipped with a re-centering device mounted on non-tilting vehicles but subject to $I = Ip > Ic$ . This is included in Annex C;

h) Instead of using the algebraic calculations given in this Annex to define a maximum construction gauge, it is possible to use the graphical method in Annex D.

## A.1.2 Dimensional tolerances on vehicles

### A.1.2.1 General principles

The dimensions of a finished vehicle in loading condition “dead mass” as defined by EN 15663:2017+A1:2018 shall remain within the maximum construction gauge with the following permitted tolerances:

a) 0,0025 m for any semi-width $b_{veh}$ of body, bogie or running gear taken separately;

b) for any height $h_{veh}$ of the finished vehicle:

— 0,010 m on the heights of upper parts of the gauge for the vehicle profile (see Figure A.10);

— 0,005 m per suspension stage on the heights of lower parts of the gauge (see Figure A.3), if vertical suspension displacements correspond to a bottoming displacement.

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c) a dissymmetry smaller than $\eta_{0,r}$.

These tolerances cannot be adopted to increase the nominal dimensions of the vehicles systematically.

#### A.1.2.2 Dimensional checking on a finished vehicle

— Lateral measurements:

It is considered that the semi-widths $b_{veh}$ with respect to the track centreline cannot be measured accurately in practice on the finished vehicle. This is caused by residual lateral displacement in the suspension (hysteresis) or wheel to rail clearance. Therefore, it is only necessary for a completed vehicle profile to comply with the requirement on the dissymmetry angle given in item c) of A.1.2.1 when set on the running gear.

Item a) of A.1.2.1 is related to the semi-width $b_{veh}$ of each part of the vehicle, i.e. body, bogie or running gear, measured separately after manufacturing and completion, but before the body is put on the running gear.

— Vertical measurements:

Item b) of A.1.2.1 is related to the finished vehicle, when the body is set on the running gear and the vehicle at a standstill is on a level track.

### A.1.3 Applicability of this annex

The formulae given in this annex are generally applicable to vehicle configurations shown below (see Figure A.1):

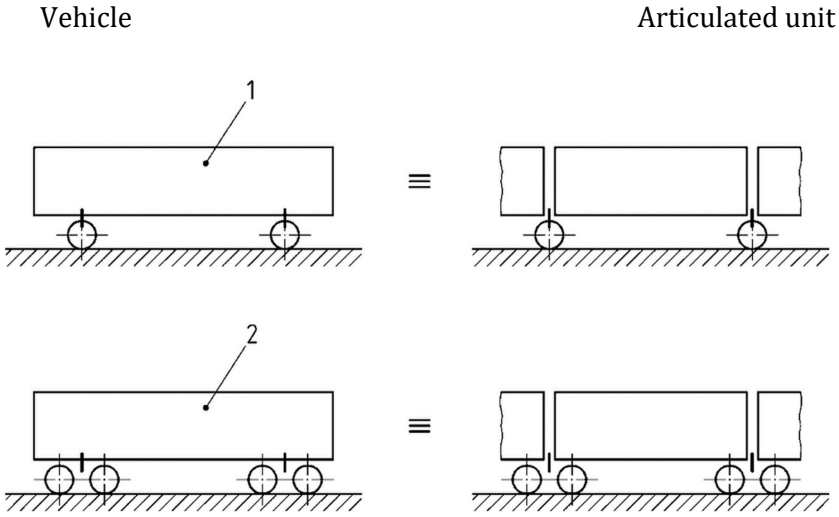
a) vehicles not fitted with bogies with the body sprung on two wheelsets. In the case of vehicles with bodies sprung on a number of different wheelsets, it will be necessary to adapt the formulae to the actual geometric conditions;

b) bogie vehicles with the body sprung on two bogies with two wheelsets. In the case of vehicles with more than two bogies or fitted with bogies with more than two wheelsets or fitted with one bogie and one wheelset, it will be necessary to adapt the formulae to the actual geometric conditions;

c) articulated unit: Figure A.1 illustrates the calculation equivalence between non-bogie and bogie vehicles with symmetrical articulated units;



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**Key**

1 2 independent wheelsets

2 2-bogies

**Figure A.1 — Correspondence between separate vehicles and articulated units**

d) for non-conventional vehicles, a new process according to geometric configurations shall be determined to prove that the vehicle complies with the gauge. It is also possible to use the graphical method described in Annex D.

### A.1.4 Vehicles with non-coincident bogie centre and rotation point

In the case of vehicles with bogies where the axis of rotation is not in the centre of the bogie, in order to determine the $a$ and $n$ values, the cross point of the bogie longitudinal centreline with that of the vehicle body will be considered as a theoretical centre, determined graphically, when the vehicle is on radius curve $R_{min}$, considering the wheelsets centred on the track and without lateral suspension displacements. If $y$ is the distance from this theoretical centre to the geometrical centre of the bogie (at an equivalent distance from the two outermost wheelsets), $\frac{p_A^2}{4}$ shall be replaced by $\left(\frac{p_A^2}{4} - y^2\right)$, and $\frac{p_B^2}{4}$ by $\left(\frac{p_B^2}{4} - y^2\right)$ in the formulae.

### A.1.5 Bogie classes

For the purposes of this standard, bogies are classified as follows:

— motor bogie: bogie, the wheelsets of which are considered as powered if the adhesion coefficient $\mu \geq 0{,}19$;

— trailing bogie: bogie, the wheelsets of which are not considered as powered if the adhesion coefficient $\mu < 0{,}19$;



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— mixed bogie: bogie with powered wheelset and trailing wheelset. It is considered the motor bogie if the motor wheelset adhesion coefficient is greater than or equal to 0,19.

The adhesion coefficient is calculated with the Formula (A.1):

$$\mu = \frac{Fw}{g \cdot M_e} \tag{A.1}$$

The maximum value for $\mu$ shall be considered in relation to the worst combination of traction force (failure mode excluded) and wheelset load.

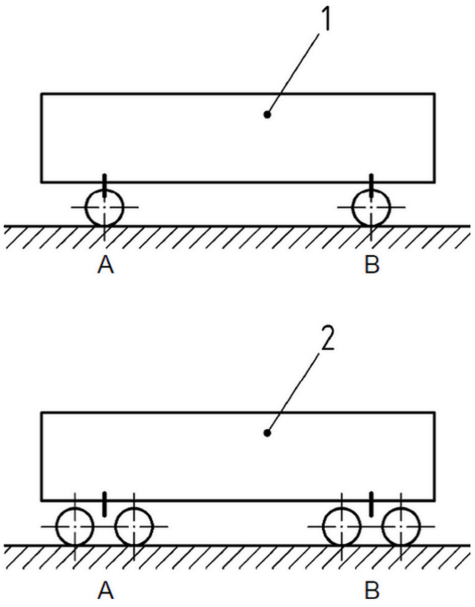
### A.1.6 Designation of running gear

In this standard, both independent wheelsets and both bogies of a vehicle are designated A or B, as shown in Figure A.2.

For vehicles with one motor bogie and one trailing bogie, A corresponds to the motor one and B to the trailing one.

For all other cases A is selected indifferently.

For the sections located between the end wheelsets or the bogie pivots, $n_{I,A}$ is always attached to the same wheelset or bogie pivot – A.




**Key**

1 vehicle fitted with independent wheelsets

2 vehicle fitted with bogies

**Figure A.2 — Designation of running gear**



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## A.2 Determination of the vehicle heights

### A.2.1 General

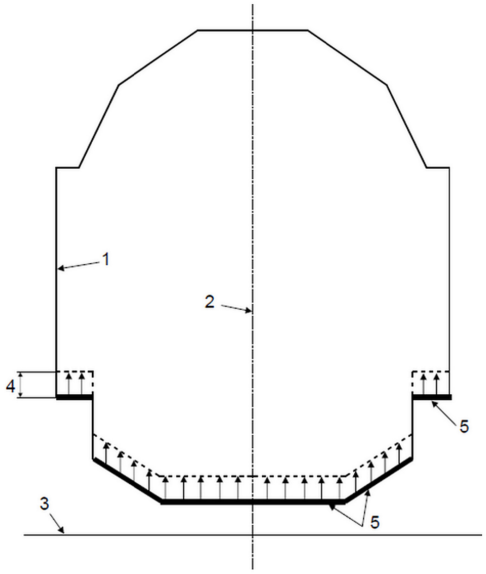
The minimum heights are determined for the lower part of the vehicle (lower parts of the gauge) and intermediate non-vertical lines on the reference profile.

The maximum heights are determined for the upper part of the vehicles (upper parts of the gauge).

### A.2.2 Determination of the minimum heights above running plane

#### A.2.2.1 General

The minimum heights above running plane of a vehicle in loading condition “dead mass” as defined by EN 15663:2017+A1:2018 and its components located close to the lower part of a gauge as shown in Figure A.3, are determined taking into account the vertical displacements and vertical reductions described in the following subclauses.




**Key**

1 reference profile

2 centreline of reference profile

3 running plane

4 vertical reductions $E_{v,u,i}$ , $E_{v,u,a}$

5 considered parts of the reference profile

**Figure A.3 — Determination of the minimum heights**

#### A.2.2.2 Overall reductions to be taken into account to determine the minimum heights above running plane

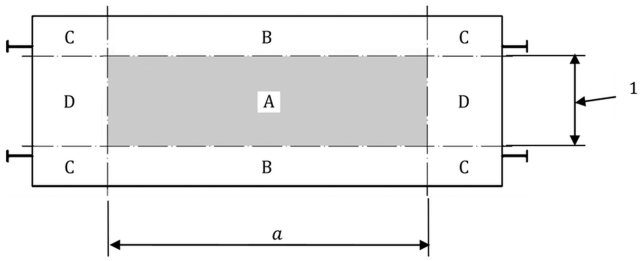
##### A.2.2.2.1 General principles

As shown in Figure A.4, in order to calculate the vertical reductions, the carbody is split into separate zones based on the suspension design.

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**Key**

1 $2 \cdot b_2$ or $2 \cdot b_1$

**Figure A.4 — support polygon zones**

The Table A.1 sums up for each zone A, B, C, D the elements to take into account in order to determine the deflections values. These values are to be adapted according to the studied vehicle.



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**Table A.1 — Vertical reduction values**

| | | | **Locomotives, coaches, multiple units, railcars** | **Wagons (single suspension level)** | **Bogies (single suspension level or primary suspension only)** See Note 6 |
|---|---|---|---|---|---|
| **ZONE A** | Suspension displacements | a | $Aff$ | $Aff$ | $Aff$ |
| | Clearances to the side bearers | | $J\frac{b}{b_G}$ | $J\frac{b}{b_G}$ | – |
| | Wheel wear | | $Usr$ | $Usr$ | $Usr$ |
| | Body camber | | 0 | $Flc$ | – |
| | Vertical curve | | $e_{u,i}$ | $e_{u,i}$ | $e_{u,i}$ |
| | Rules for bottom lines of gauge | b | $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}$ or $e_{i,fb}$ | $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}$ or $e_{i,fb}$ | $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}$ or $e_{i,fb}$ |
| **ZONE B** | Suspension displacements | a | $Aff + 0{,}1 \cdot s \cdot (b - b2)$ See NOTE 1 | $Aff + \Delta Aff \frac{(b - b_1)}{2 \cdot b_1}$ See Figure A.6 and NOTE 2 | ***Aff*** See NOTE 5 |
| | Clearances to the side bearers | | $J\frac{b}{b_G}$ | $J\frac{b}{b_G}$ | – |
| | Wheel wear | | $Usr$ | $Usr$ | $Usr$ |
| | Body camber | | 0 | $Flc$ | *0* |
| | Vertical curve | | $e_{u,i}$ | $.e_{u,i}.$ | $e_{u,i}$ |
| | Rules for bottom lines of gauge | b | $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}$ or $e_{i,fb}$ | $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}$ or $e_{i,fb}$ | $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}$ or $e_{i,fb}$ |
| **ZONE C** | Suspension displacements | **a** | $Max\begin{pmatrix} Aff + \Delta Aff \cdot \frac{n_a}{a} \\ Aff + 0{,}1 \cdot s \cdot (b - b_2) \end{pmatrix}$ | $Aff + \Delta Aff \frac{\sqrt{n_a^2 + (b - b_1)^2}}{\sqrt{a^2 + 4 \cdot b_1^2}}$ See NOTE 2 | $Aff + \Delta aff \cdot \frac{n_a}{p}$ See NOTE 5 |
| | Clearances to the side bearers | | $J\frac{b}{b_G}$ | $J\frac{b}{b_G}$ | – |
| | Wheel wear | | $Usr + \Delta Usr \cdot \frac{n_a}{a}$ | $Usr + \Delta Usr \cdot \frac{n_a}{a}$ | $Usr + \Delta Usr \cdot \frac{n_a}{p}$ |
| | Body camber | | 0 | $Flc$ | *0* |
| | Vertical curve | | $e_{u,a}$ | $e_{u,a}$ | $e_{u,a}$ |
| | Rules for bottom lines of gauge | b | $e_{a,mh}$ or $e_{a,fb}$ | $e_{a,mh}$ or $e_{a,fb}$ | $e_{a,mh}$ or $e_{a,fb}$ |



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| | | | **Locomotives, coaches, multiple units, railcars** | **Wagons (single suspension level)** | **Bogies** (single suspension level or primary suspension only) |
|---|---|---|---|---|---|
| **ZONE D** | Suspension displacements | a | $Aff + \Delta Aff \cdot \frac{n_a}{a}$ See Figure A.5 | $Aff + \Delta Aff \cdot \frac{n_a}{a}$ See Figure A.5 | $Aff + \Delta aff \cdot \frac{n_a}{p}$ See Figure A.5 |
| | Clearances to the side bearers | | $J \frac{b}{b_G}$ | $J \frac{b}{b_G}$ | – |
| | Wheel wear | | $Usr + \Delta Usr \cdot \frac{n_a}{a}$ | $Usr + \Delta Usr \cdot \frac{n_a}{a}$ | $Usr + \Delta Usr \cdot \frac{n_a}{p}$ |
| | Body camber | | 0 | $Flc$ | *0* |
| | Vertical curve | | $e_{u,a}$ | $e_{u,a}$ | $e_{u,a}$ |
| | Rules for bottom lines of gauge | b | $e_{a,mh}$ *or* $e_{a,fb}$ | $e_{a,mh}$ *or* $e_{a,fb}$ | $e_{a,mh}$ *or* $e_{a,fb}$ |

NOTE 1 The flexibility coefficient value s covers the remaining suspension displacement possibilities. The $S$ value for vertical displacements can be different to the $S$ value used for lateral quasi-static displacement $z_{cin}$. For example, if $Aff$ is equal to bottoming displacement for zone A, then $S$ can be regarded as zero for zones B and C.

NOTE 2 Depending on the suspension architecture, parameter $b_1$ can be replaced by $b_2$ in the formulae above.

NOTE 3 Clearances to the side bearers are used if existing.

NOTE 4 It is possible to replace $b$ by $b_{CR}$.

For the bogie, depending on the suspension architecture, an additional vertical displacement due to rolling shall be taken into account. Therefore the flexibility coefficient value $S$ can be adjusted for the primary suspension level.

Secondary suspended components shall be calculated according to the specifications in the column for locomotives, coaches, multiple units

NOTE 5 For the purposes of this document, multiple unit (MU) trains considered contain motor vehicle(s) with one motor bogie and one trailer bogie.

a These elements shall be accumulated for all vehicles to obtain $E_{v,u,i}$, $E_{v,u,a}$

b This element shall be added if relevant for the vehicle type under consideration. For the bottom lines of the gauge, the effect of vertical curve according to A.2.2.2.5 shall be replaced by A.2.2.2.6.

$Aff$ Suspension displacement value, including spring tolerance as specified in A.2.2.2.4.

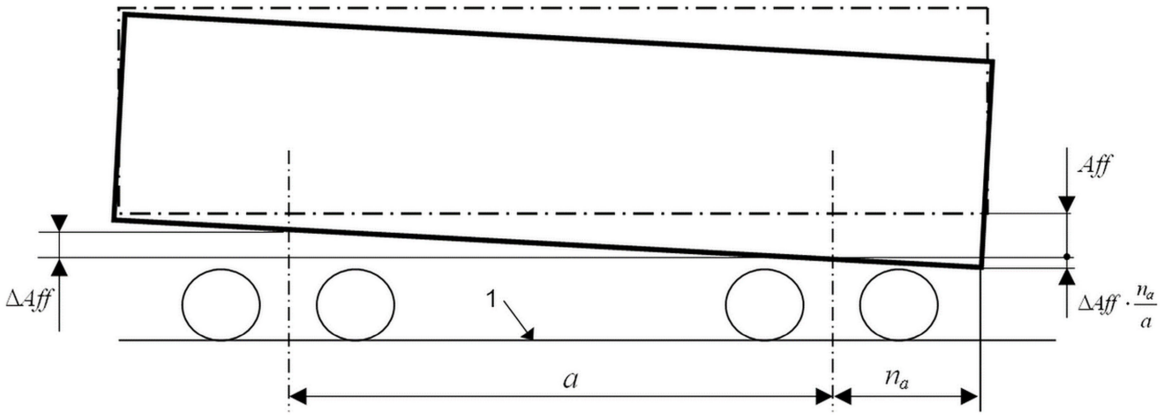
$\Delta Aff$ Difference in suspension displacement, applicable for zones C and D in the longitudinal direction and for zones B and C for lateral direction.

Suspensions with steel or rubber springs: In the longitudinal direction, as show in Figure A.5, a difference in the vertical displacements $\Delta Aff$ of the two bogies shall be taken into account, considering $Aff$ in one bogie and the suspension displacement due to the maximum static load $Aff_{stl}$ in the other.



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Suspensions with air springs: In the longitudinal direction, when a pneumatic link does not exist between the suspensions of the two bogies, a difference in the downward displacements shall be taken into account. In this case, a suspension displacement $Aff$ is considered for one of the bogies and suspension displacement due to the maximum static load with air spring inflated is considered for the second bogie. When a pneumatic link exists between the suspensions of the two bogies, the air spring of the second bogie is considered deflated.

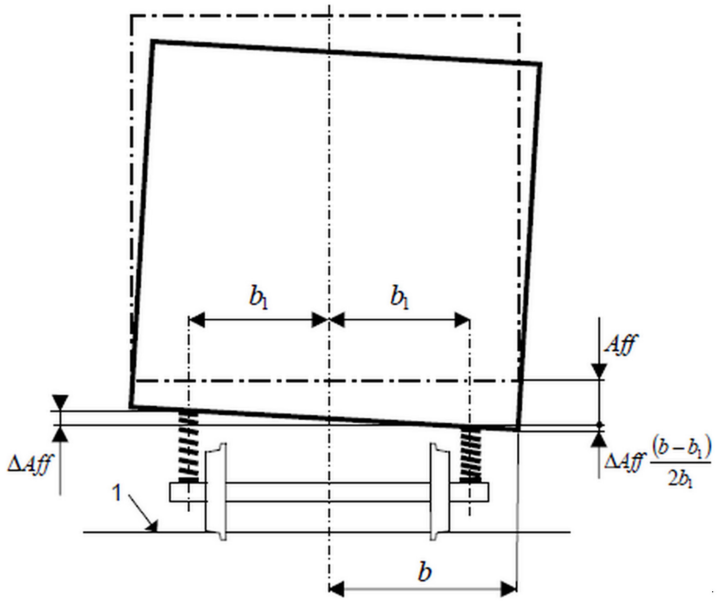



**Key**

1 running plane

**Figure A.5 — Pitch due to different vertical suspension displacements**

In the lateral direction, the difference in the displacements of the two stages of suspension, as shown in Figure A.6, is obtained considering the deflection under maximum static load for the first one and the deflection $Aff$ defined in Table A.2 for the second one.




**Key**

1 running plane

**Figure A.6 — Roll due to different vertical suspension displacements**



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#### A.2.2.2.2 Wear displacements

These displacements concern the following parts:

— wheels: maximum wear for all types of vehicle or wear allowed between adjustments (if compensatory adjustments are planned during maintenance);

— miscellaneous parts: maximum wear – examples: side-bearers, brake rigging, etc., for all vehicles and for each special assembly;

— axle boxes: wear ignored.

#### A.2.2.2.3 Structure deformation displacement – $Flc$

a) wheelsets: sag ignored;

b) bogie frame: sag ignored;

c) body:

1) twist: ignored;

2) lateral bending: ignored;

3) sag: ignored for all vehicles except wagons for which the sag along the carbody has to be taken into account under the effect of an exceptional payload as defined in EN 15663:2017+A1:2018 increased by 30 % to take into account dynamic deformations.

#### A.2.2.2.4 Suspension displacement – $Aff$

The following displacements of the primary and secondary suspension are to be taken into account:

a) steel spring and rubber spring:

**Table A.2 — Suspension displacement for different types of rolling stock**

| Type of rolling stock | Suspension displacement |
|---|---|
| Locomotives | Deflection under static load with an overload of 30 % of the sprung mass in load condition “design mass in working order” as defined in EN 15663:2017+A1:2018 or bottoming |
| Wagons | Total displacement (bottoming) |
| Coaches and vans, special wagons, multiple units, railcars bogies | Deflection under static load with an overload of 30 % of the sprung mass in load condition “design exceptional mass” as defined in EN 15663:2017+A1:2018 or bottoming |

In case the displacements are not calculated on bottoming, the effect of tolerances of the stiffness of the springs has to be taken into account;

NOTE Special wagons: wagons whose loading surface height above the running plane is reduced to allow maximum loading capacities in the vertical direction. This category includes what are sometimes called low floor wagons: pocket wagons, “rolling-road” wagons and similar wagons;



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b) air spring:

total deflection with air springs deflated. If there are back-up steel or rubber suspensions, the rules described in a) have to be applied.

#### A.2.2.2.5 Vertical reduction formulae for vertical curves

All vehicles shall be able to pass over convex or concave vertical curve of radius $R_{v,min}$ . The heights of the vehicle gauge relative to the running plane shall be increased by the value $e_{u,i}$ or $e_{u,a}$:

— Formula (A.2) is applicable for the sections located between the end wheelsets or the bogie pivots:

$$e_{u,i} = \left[ \frac{a \cdot n_{i,A} - n_{i,A}^2 + \frac{a - n_{i,A}}{a} \cdot \frac{p_A^2}{4} + \frac{n_{i,A}}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,min}} - S_{v,u} \right]_{>0} \quad \text{(A.2)}$$

— for the sections located beyond the end wheelsets or the bogie pivots:

— Formula (A.3) is applicable for the sections beyond bogie A:

$$e_{u,a} = \left[ \frac{a \cdot n_a + n_a^2 - \frac{n_a + a}{a} \cdot \frac{p_A^2}{4} + \frac{n_a}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,min}} - S_{v,u} \right]_{>0} \quad \text{(A.3)}$$

— Formula (A.4) is applicable for the sections beyond bogie B:

$$e_{u,a} = \left[ \frac{a \cdot n_a + n_a^2 + \frac{n_a}{a} \cdot \frac{p_A^2}{4} - \frac{n_a + a}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,min}} - S_{v,u} \right]_{>0} \quad \text{(A.4)}$$

For designation of bogies A and B, see A.1.6, for basic data see Annex E.

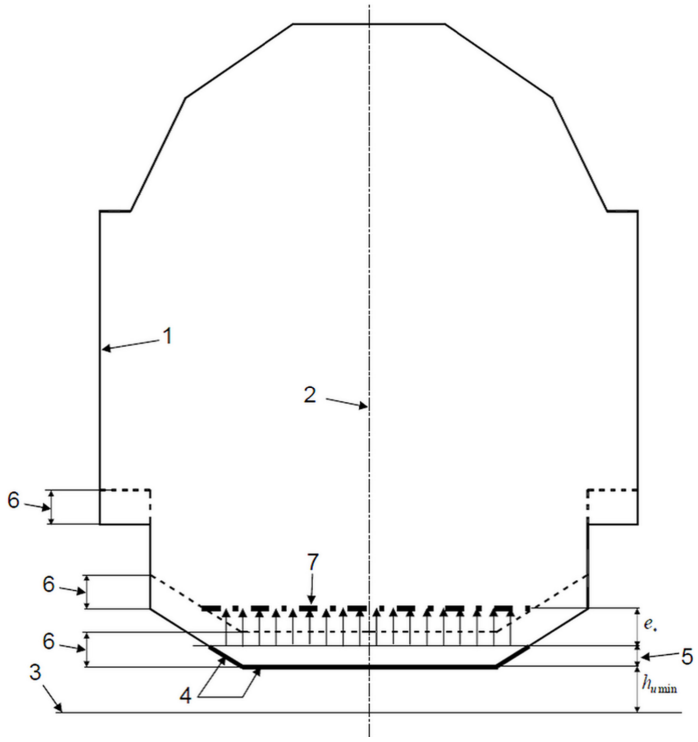
#### A.2.2.2.6 Rules for bottom lines of gauge – marshalling hump and embarkation onto ferries

##### A.2.2.2.6.1 General

The Figure A.7 illustrates the rules applicable for bottom lines of gauge.



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**Key**

1 reference profile

2 centreline of reference profile

3 running plane

4 bottom lines

5 effect of suspension displacements, clearances to the side bearers, wheel wear and body sag

6 $E_{v,u,i}, E_{v,u,a}$ – see Table A.1, footnote a

7 maximum construction gauge

e = $e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}, e_{i,fb}, e_{a,mh}$ *or* $e_{a,fb}$ – see Table A.1, footnote b

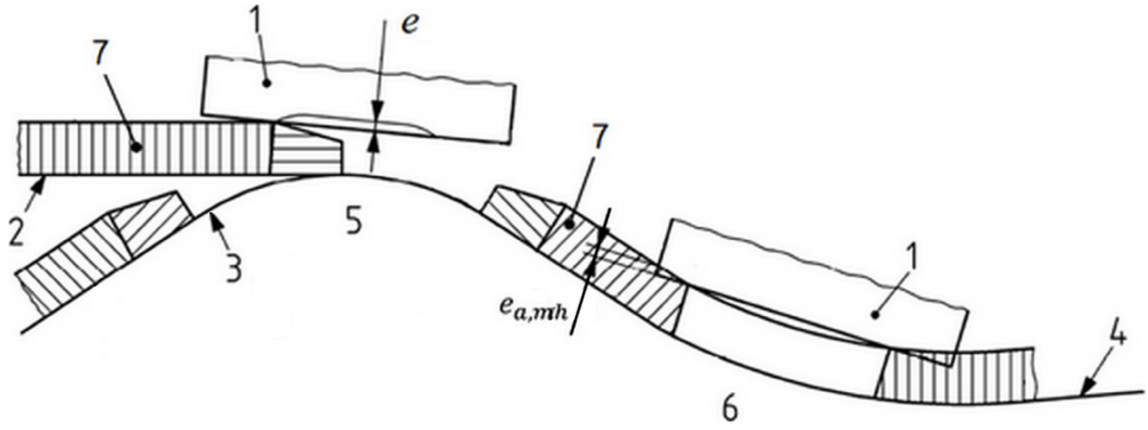
**Figure A.7 — Bottom lines of gauge**

### A.2.2.2.6.2 Vertical reduction formulae for passing over marshalling humps

Figure A.8 shows the vertical reductions to be taken into account for vehicles passing over the marshalling hump.



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**Key**

| | |
|---|---|
| 1 | vehicle |
| 2 | shunting ramp |
| 3 | classic hump |
| 4 | running plane |
| 5 | convex |
| 6 | concave |
| 7 | track brake |
| $e$ | $\max\left(e_{i,mh}, e_{i,1}, e_{i,2}, e_{i,3}, e_{i,4}\right)$ |

**Figure A.8 — Passing over marshalling hump**

NOTE Associated lateral rules are given in A.3.3.1.

### a – Sections located between the end wheelsets or between the bogie pivots

The minimum height of vehicles, taking into account vertical displacements as defined in Table A.1 except for $e_{u,i}$ (see Table A.1, Note b), shall be at least equal to $h_{umin}$ increased by the maximum value of, $e_{i,mh}, e_{i,1}, e_{i,2} e_{i,3}$ and $e_{i,4}$ calculated with the Formulea (A.5) to (A.11):

### a1 – Convex curve

Vehicles shall be able to pass over convex curves $R_{v,cnv}$, without any part other than the wheel flange dropping below the running plane.

$$e_{i,mh} = \left[ \frac{a \cdot n_{i,A} - n_{i,A}^2 + \frac{a - n_{i,A}}{a} \cdot \frac{p_A^2}{4} + \frac{n_{i,A}}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,cnv}} - h_{u\,min} \right]_{>0} \tag{A.5}$$

### a2 – Track brakes

Vehicles shall be capable of passing over track brakes in an active or non-active position located on non-vertically curved track and reaching to $h_{umin}$ above the running plane.



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$$e_{i,1} = \frac{n_i}{a} \cdot \frac{(a - n_i - X)^2}{2 \cdot R_{v,cnv}} \quad \text{(A.6)}$$

$$e_{i,2} = \frac{2 \cdot (a - X)^3}{27 \cdot a \cdot R_{v,cnv}} \quad \text{(A.7)}$$

$$e_{i,3} = \left(\frac{27}{4} \cdot \frac{n_i}{a - X}\right) \cdot \left(1 - \frac{n_i}{a - X}\right)^2 \cdot \left(\frac{2 \cdot a^2}{27 \cdot R_{v,cnv}} - e_v\right) \quad \text{(A.8)}$$

$$e_{i,4} = \frac{2 \cdot a^2}{27 \cdot R_{v,cnv}} - e_v \quad \text{(A.9)}$$

**b – Sections located beyond the end wheelsets or beyond the bogie pivots**

Vehicles shall be capable of passing over track brakes in an active or non-active position located on vertically curved track $R_{v,cnc}$ and reaching to $h_{umin}$ above the running plane.

The minimum height of vehicles, taking into account vertical displacements as defined in Table A.1 except for $e_{u,a}$ (see footnote b Table A.1), shall be at least equal to $h_{umin}$ increased by $e_{a,mh}$ :

— Formula (A.10) is applicable for the sections beyond bogie A:

$$e_{a,mh} = \frac{a \cdot n_a + n_a^2 - \frac{n_a + a}{a} \cdot \frac{p_A^2}{4} + \frac{n_a}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,cnc}} \quad \text{(A.10)}$$

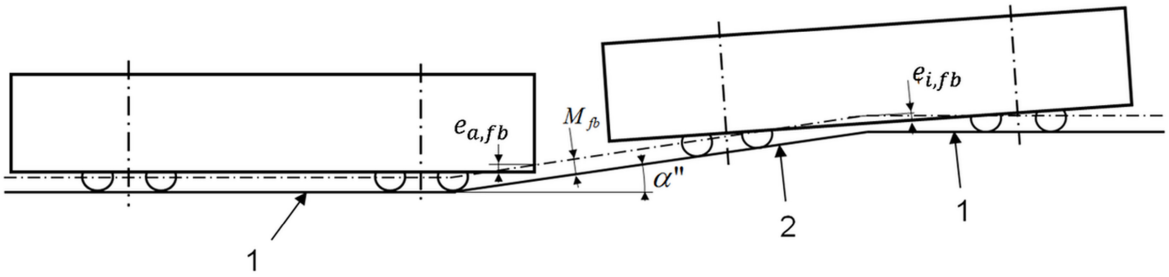
— Formula (A.11) is applicable for the sections beyond bogie B:

$$e_{a,mh} = \frac{a \cdot n_a + n_a^2 + \frac{n_a}{a} \cdot \frac{p_A^2}{4} - \frac{n_a + a}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,cnc}} \quad \text{(A.11)}$$

For designation of bogies A and B, see A.1.6

**A.2.2.2.6.3 Conditions for embarkation onto ferries**

Vehicles shall be capable of passing over vertical transitions made by a loading ramp between ferry and quay. Figure A.9 shows the vertical reductions.




**Key**

1 running plane of ferry or quay
2 running plane of loading ramp

**Figure A.9 — Embarkation onto ferry**



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The minimum height of vehicles, taking into account vertical static displacements as defined below, shall be at least equal to $M_{f,b}$ increased by the value of $e_{i,fb}$ or $e_{a,fb}$ calculated with following formulae:

— Formula (A.12) is applicable for the sections located between the end wheelsets or the bogie pivots:

$$e_{i,fb} = \frac{n_i \cdot (a - n_i)}{a} \cdot \tan(\alpha'') \quad \text{(A.12)}$$

— Formula (A.13) is applicable for the sections located beyond the end wheelsets or the bogie pivots:

$$e_{a,fb} = n_a \cdot \tan(\alpha'') \quad \text{(A.13)}$$

For the fixed allowance $M_{f,b}$ and the angle made by the link span $\alpha''$ - see prEN 15273-4:2023.

Vertical static displacement to take into account:

— maximum allowed wheel wear $Usr$, see A.2.2.2.2;

— structure deformation of the carbody due to the static loading $Flc$, see A.2.2.2.3;

— downward suspension displacement value $Aff_{stl}$ including spring tolerances in static loading under maximum or exceptional payload as defined in EN 15663:2017+A1:2018.

Vertical suspension displacements $Aff_{stl}$ are taken into account according to A.2.2.2.4 with the following exception: for steel and rubber springs (See A.2.2.2.4, a)) and for any vehicle type the static deflection only shall be considered. The dynamic deflection and pitch due to suspension movements is covered by the allowance $M_{f,b}$.

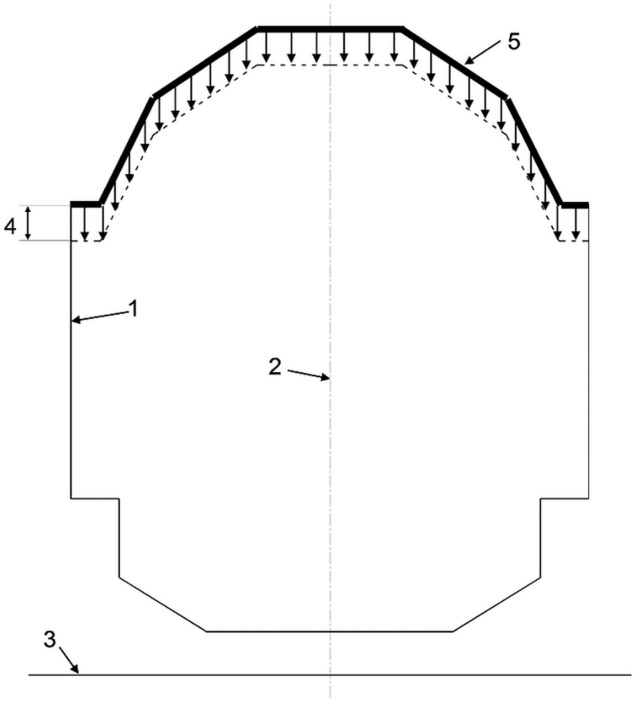
## A.2.3 Determination of maximum heights above running plane

### A.2.3.1 General

The maximum heights above running plane of a vehicle in loading condition “dead mass” as defined by EN 15663:2017+A1:2018, and its components located close to the upper part of the gauge as shown in Figure A.10 are determined taking into account the sum of the vertical displacements (see A.2.3.2 and A.2.3.3) and vertical reductions (see A.2.3.4) corresponding to $E_{v,o,i}$ or $E_{v,o,a}$.



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**Key**

1 reference profile

2 centreline of reference profile

3 running plane

4 vertical reductions $E_{v,o,i}$, $E_{v,o,a}$

5 considered parts of the reference profile

**Figure A.10 — Determination of maximum heights**

### A.2.3.2 Bending effect of structures

Body: longitudinal sag disregarded, except for wagons.

### A.2.3.3 Suspension extension

The extension of the suspension is taken into account by considering a 0,010 m displacement for each level of suspension.

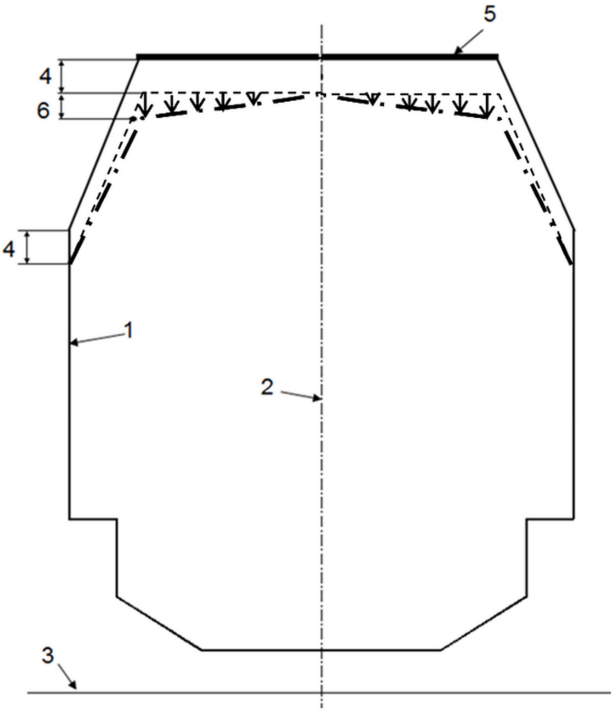
The roll due to the dissymmetry and the pitch due to suspension movements are ignored.

If the upper horizontal part of gauges present a half-width greater than one metre, the vertical component $z_{cin,v}$ of the roll displacement shall be added to $E_{v,o,i}$ or $E_{v,o,a}$, as illustrated in Figure A.11.

NOTE 1 for example $z_{cin,v}$ is applicable for the top of gauges GC, GB2, BE4, SEC, PTc, GEC16.



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**Key**

1 reference profile

2 centreline of reference profile

3 running plane

4 vertical reductions $E_{v,o,i}$, $E_{v,o,a}$

5 concerned parts

6 vertical quasi static displacements $z_{cin,v}$

**Figure A.11 — Upper line of gauge**

If b > 1m, Formula (A.14) or Formula (A.15) are to be applied:

$$z_{cin,v} = s \cdot b \cdot \frac{D_0}{L} + (s - s_0)_{>0} \cdot b \cdot \frac{(D_{max} - D_0)}{L} \quad \text{(A.14)}$$

or

$$z_{cin,v} = s \cdot b \cdot \frac{I_0}{L} + (s - s_0)_{>0} \cdot b \cdot \frac{(I_{max} - I_0)}{L} \quad \text{(A.15)}$$

Otherwise $z_{cin,v}$ is not taken into account.

NOTE 2 $z_{cin,v}$ is only applied on the horizontal upper line of the reference profile.

### A.2.3.4 Vertical curves

The heights of the rolling stock relative to the running plane taking into account vertical displacements as defined in A.2.3.2 and A.2.3.3 shall be reduced:



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— Formula (A.16) is applicable for the sections located between the end wheelsets or the bogie pivots:

$$e_{o,i} = \left[ \frac{a \cdot n_{i,A} - n_{i,A}^2 + \frac{a - n_{i,A}}{a} \cdot \frac{p_A^2}{4} + \frac{n_{i,A}}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,min}} - S_{v,o} \right]_{>0} \quad \text{(A.16)}$$

— for the sections located beyond the end wheelsets or the bogie pivots:

— Formula (A.17) is applicable for the sections beyond bogie A:

$$e_{o,a} = \left[ \frac{a \cdot n_a + n_a^2 - \frac{n_a + a}{a} \cdot \frac{p_A^2}{4} + \frac{n_a}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,min}} - S_{v,o} \right]_{>0} \quad \text{(A.17)}$$

— Formula (A.18) is applicable for the sections beyond bogie B:

$$e_{o,a} = \left[ \frac{a \cdot n_a + n_a^2 + \frac{n_a}{a} \cdot \frac{p_A^2}{4} - \frac{n_a + a}{a} \cdot \frac{p_B^2}{4}}{2 \cdot R_{v,min}} - S_{v,o} \right]_{>0} \quad \text{(A.18)}$$

For designation of bogies A and B, see A.1.6.

## A.3 Determination of the vehicle semi-widths

### A.3.1 General

Taking into account the lateral displacements of vehicles (specified in the associated rules for each gauge), the semi-widths of the vehicles considered shall not exceed the corresponding semi-width of the reference profile of the gauge, reduced by the maximum values $E_i$ or $E_a$.

For each section along the vehicle, reductions $E_i$ for $n_{i,A}$ or $E_a$ for $n_a$ are calculated by applying the formulae given in the following points with basic data for each kinematic gauge from prEN 15273-4:2023. The value of $R$, with $\infty \geq R \geq R_{min}$, to be considered is that one which gives the highest value for $E_i$ or $E_a$.

These displacements are the sum of the following displacements:

a) quasi-static displacements resulting from the roll of the vehicle on its suspension and its dissymmetry (when this is greater than $\eta_{0,r}$);

b) lateral displacements resulting from the vehicle operating along curves and straight track (overthrows, clearances, etc.), where the vehicle vertical centreline is considered to be perpendicular to the running plane;

c) lateral bending of the vehicle body for special types of wagon or heavily-loaded wagons for which these values are particularly high. Otherwise this is generally disregarded.



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## A.3.2 Quasi-static displacements

### A.3.2.1 General

The flexibility coefficient value $s$ can vary according to the loading, the cant value or cant deficiency value.

The load cases “design mass in working order” or “dead mass” (if the gauge calculation considers the empty vehicle) and “design exceptional mass” as defined in EN 15663:2017+A1:2018 should be considered in the determination of the flexibility coefficient.

Value $s$ is determined by vehicle designers according to the technology and characteristics of the vehicle.

Value $s$ is checked on a finished vehicle by test following EN 14363:2016+A2:2022 (method 1 or method 2).

The values of the flexibility coefficient s should be adapted according to the test result.

Depending on the point considered, the results of the calculation for the two s values can be combined in order to obtain the critical case (e.g. for a given profile using $s_{MVD}$ for $P$ and higher, and $s_{MXD}$ for point lower than $P$).

Value $h_c$ can be taken into account with regard to one of the height of the vehicle bump stops. For more detail see prCEN/TR1273-5:2023, 7.1.1.4.3.

### A.3.2.2 General cases

For sprung parts of height $h$, the above terms give the Formula (A.19)a) or Formula (A.19)b):

$$z_{cin} = \frac{s \cdot D_0}{L} \cdot (h - h_c)_{>0} + \left\{ \tan\left[ \eta_0 - \eta_{0,r} \right]_{>0} \right\} \cdot |h - h_c| + \left[ \frac{s \cdot (D_{max} - D_0)}{L} \cdot (h - h_c)_{>0} - \frac{s_0 \cdot (D_{max} - D_0)}{L} \cdot (h - h_{c0})_{>0} \right]_{>0} \quad \text{(A.19a)}$$

Or

$$z_{cin} = \frac{s \cdot I_0}{L} \cdot (h - h_c)_{>0} + \left\{ \tan\left[ \eta_0 - \eta_{0,r} \right]_{>0} \right\} \cdot |h - h_c| + \left[ \frac{s \cdot (I_{max} - I_0)}{L} \cdot (h - h_c)_{>0} - \frac{s_0 \cdot (I_{max} - I_0)}{L} \cdot (h - h_{c0})_{>0} \right]_{>0} \quad \text{(A.19b)}$$

These formulae apply if the roll centre is below the centre of gravity. Otherwise, formulae for passive tilting vehicles apply – see B.3.

NOTE It is possible to replace $h$ by $h_{CR}$ for points above the roll centre at which the width $b_{CR}$ decreases with the height, as well as for points below the roll centre at which the width $b_{CR}$ increases with the height.

If the roll centre height and the flexibility coefficient of different bogies varies, the Formula (A.19)a) or Formula (A.19)b) for $z_{cin}$ should be adapted or the most conservative value should be used.

### A.3.2.3 Effect of side bearer clearances

For sprung parts of height $h$, the above the side bearer give the Formula (A.20)a) or Formula (A.20)b):



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$$z_{cin} = \frac{s \cdot D_0}{L} \cdot \left(h - h_c\right)_{>0} + \left\{ \tan\left[ \eta_0^{'} + \left( \arctan \frac{\left(J - 0{,}005\right)_{>0}}{b_G} \right) \cdot \left(1 + s\right) - \eta_{0,r} \right]_{>0} \right\} \cdot \left|h - h_c\right| + \left[ \frac{s \cdot \left(D_{max} - D_0\right)}{L} \cdot \left(h - h_c\right)_{>0} - \frac{s_0 \cdot \left(D_{max} - D_0\right)}{L} \cdot \left(h - h_{c0}\right)_{>0} \right]_{>0}$$

. (A.20a)

or

$$z_{cin} = \frac{s \cdot I_0}{L} \cdot \left(h - h_c\right)_{>0} + \left\{ \tan\left[ \eta_0^{'} + \left( \arctan \frac{\left(J - 0{,}005\right)_{>0}}{b_G} \right) \cdot \left(1 + s\right) - \eta_{0,r} \right]_{>0} \right\} \cdot \left|h - h_c\right| + \left[ \frac{s \cdot \left(I_{max} - I_0\right)}{L} \cdot \left(h - h_c\right)_{>0} - \frac{s_0 \cdot \left(I_{max} - I_0\right)}{L} \cdot \left(h - h_{c0}\right)_{>0} \right]_{>0}$$

(A.20b)

Where:

$\eta_0^{'}$ is the dissymmetry corresponding to a side bearer clearance of 5 mm.

NOTE It is possible to replace $h$ by $h_{CR}$. For points above the roll centre at which the width $b_{CR}$ decreases with the height, as well as for points below the roll centre at which the width $b_{CR}$ increases with the height.

#### A.3.2.4 Particular case for the lower parts

In Formulae (A.19) and (A.20), the parts of $z_{cin}$ in relation with cant and cant deficiency take into account the higher parts only with $\left(h - h_c\right)_{>0}$ as $q + w$ is generally considered higher than $z_{cin}$ in the lower part of the reference profile.

Nevertheless, in the particular case when $s > s_0$ it is necessary to check if the lower part remains inside the reference profile including lateral projection in the opposite side of the displacement $q + w$ for $D_{max}$ and $I_{max}$.

This can be checked by formulae, graphical method or simulation.

### A.3.3 Lateral reductions – general formulae

#### A.3.3.1 General

The various operating positions of a vehicle on the track depend on the lateral clearances of the different parts connecting the body of the vehicles to the track and the design of the vehicle running gear (independent wheelsets, motor bogies, trailing bogies, etc.).

The different positions the vehicle can assume on the track should be studied in order to take account of any angular displacement coefficient $A_n$ to be applied to certain terms to be used for the calculation of the inside reductions $E_i$ and outside reductions $E_a$:

— for cases of wheelset configuration not shown in the Tables A.3 to A.6, the track position conditions to be taken into account shall be the most unfavourable;

— for articulated vehicles, it is recommended that the operating position indicated for the standard 2-bogie vehicles be taken;

— the vehicles track operation position below is given for vehicles fitted with non-steerable wheelsets. For vehicles with other wheel set types (for example independent wheels) an adapted displacement factor can be used with an appropriate explanation and demonstration. If not demonstrated, the worst case of displacement factor given in Tables A.3 to A.6 shall be considered;



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— when the value of $A_2$ is zero, the bogie is considered tangential to the centreline of the track to define the values of play $w_{(R)}$ between bogie and body.

Defined kinematic gauges take into account a minimum curve radius $R_{min}$ – see value in prEN 15273-4:2023 even if the vehicle under study can pass over even smaller curve radii.

In the following formulae:

— $A_{n,A}$ is associated to the bogie – A, $A_{n,B}$ is associated to the bogie – B;

— $S_l = \frac{l - l_{nom}}{2}$ ($l = l_{max}$ for the rolling stock see prEN 15273-4:2023).

### A.3.3.2 Sections located between the end wheelsets or between the bogie pivots

#### A.3.3.2.1 General

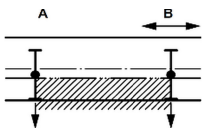
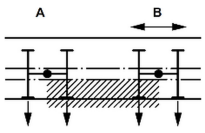
The lateral reduction for the sections located between the end wheelsets or between the bogie pivots shall be calculated with Formula (A.21).

$$E_i = \frac{a \cdot n_{i,A} - n_{i,A}^2 + A_{1,A} \cdot \frac{p_A^2}{4} + A_{1,B} \cdot \frac{p_B^2}{4}}{2 \cdot R} + A_{2,A} \cdot \frac{l_{max} - d_A}{2} + A_{2,B} \cdot \frac{l_{max} - d_B}{2} + A_{3,A} \cdot w_{i,(R),A} + A_{3,B} \cdot w_{i,(R),B} + A_{5,A} \cdot q_A + A_{5,B} \cdot q_B + z_{cin} - S_{R,i} - A_6 \cdot S_l \quad \text{(A.21)}$$

#### A.3.3.2.2 Straight track

Table A.3 shows the displacement factors for straight track.

**Table A.3 — Displacement factors for straight track**

| Vehicles | Position of vehicles in track | Case number | $A_{1,A}$ | $A_{1,B}$ | $A_{2,A}$ | $A_{2,B}$ | $A_{3,A}$ | $A_{3,B}$ | $A_{5,A}$ | $A_{5,B}$ | $A_6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicles with two wheelsets, and bogies themselves |   | (1) | | | $\frac{a - n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | | | $\frac{a - n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | 1 |
| Vehicles with bogies |   | (2) | $\frac{a - n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a - n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a - n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a - n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | 1 |

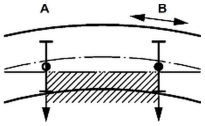
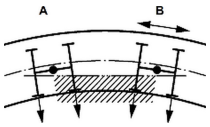
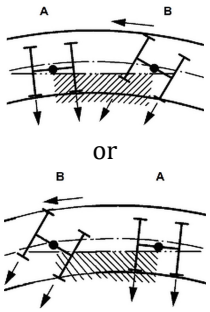
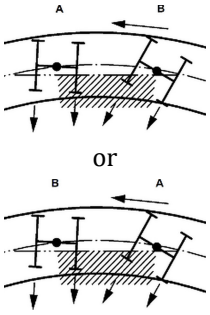


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#### A.3.3.2.3 Curved track

Table A.4 shows the displacement factors for curves

**Table A.4 — Displacement factors for curves**

| Vehicles | Position of vehicles in track | Case number | $A_{1,A}$ | $A_{1,B}$ | $A_{2,A}$ | $A_{2,B}$ | $A_{3,A}$ | $A_{3,B}$ | $A_{5,A}$ | $A_{5,B}$ | $A_6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| vehicles with two wheelsets, and bogies themselves |  | (3) | | | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | | | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | 1 |
| Vehicles with 2 motor bogies or designated as “motor” bogie |  | (4) | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | 1 |
| Vehicles with 1 bogie designated as a “motor” bogie and 1 trailing bogie or regarded as a “trailing” bogie |  | (5) | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ | 0 | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ |
| Vehicles with 2 trailing bogies or regarded as “trailing” bogies |  | (6) | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | 0 | 0 | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | $\frac{a-n_{i,A}}{a}$ | $\frac{n_{i,A}}{a}$ | 0 |

### A.3.3.3 Sections located beyond the end wheelsets or beyond the bogie pivots

#### A.3.3.3.1 General

The lateral reduction for the sections located beyond the end wheelsets or beyond the bogie pivots shall be calculated with Formula (A.22).

$$E_a = \frac{a \cdot n_a + n_a^2 - A_{1,A} \cdot \frac{p_A^2}{4} + A_{1,B} \cdot \frac{p_B^2}{4}}{2 \cdot R} + A_{2,A} \cdot \frac{l_{max} - d_A}{2} + A_{2,B} \cdot \frac{l_{max} - d_B}{2} + A_{3,A} \cdot w_{i,(R),A} + A_{3,B} \cdot w_{i,(R),B} + A_{4,A} \cdot w_{a,(R),A} + A_{4,B} \cdot w_{a,(R),B} + A_{5,A} \cdot q_A + A_{5,B} \cdot q_B + z_{cin} - S_{R,a} - S_l \quad \text{(A.22)}$$

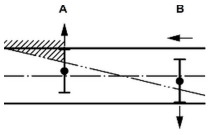
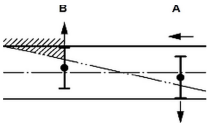
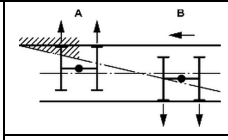
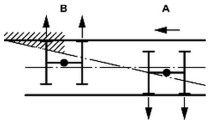
#### A.3.3.3.2 Straight track

Table A.5 shows the displacement factors for straight track.



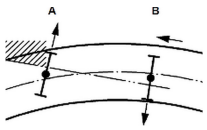
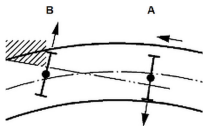
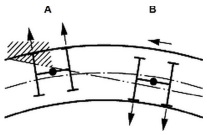
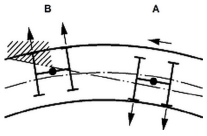
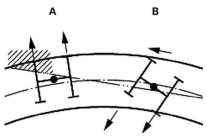
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**Table A.5 — Displacement factors for straight track**

| Vehicles | Position of vehicles in track | Case number | $A_{1,A}$ | $A_{1,B}$ | $A_{2,A}$ | $A_{2,B}$ | $A_{3,A}$ | $A_{3,B}$ | $A_{4,A}$ | $A_{4,B}$ | $A_{5,A}$ | $A_{5,B}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicles with independent wheelsets, and bogies themselves |  | (7) | | | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | | | | | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ |
| |  | (8) | | | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | | | | | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ |
| Vehicles with bogies |  | (9) | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | 0 | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ |
| |  | (10) | $-\frac{n_a}{a}$ | $-\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | 0 | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ |

### A.3.3.3.3 Curved track

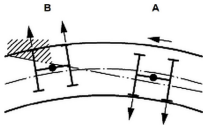
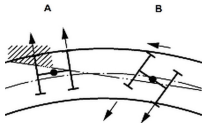
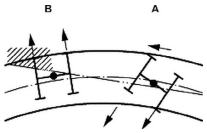
**Table A.6 — Displacement factors for curves**

| Vehicles | Position of vehicles in track | Case number | $A_{1,A}$ | $A_{1,B}$ | $A_{2,A}$ | $A_{2,B}$ | $A_{3,A}$ | $A_{3,B}$ | $A_{4,A}$ | $A_{4,B}$ | $A_{5,A}$ | $A_{5,B}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicles with independent wheelsets, and bogies themselves |  | (11) | | | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | | | | | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ |
| |  | (12) | | | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | | | | | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ |
| Vehicles with 2 motor bogies or designated as "motor" bogie |  | (13) | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | 0 | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ |
| |  | (14) | $-\frac{n_a}{a}$ | $-\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | 0 | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ |
| Vehicles with 1 bogie |  | (15) | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | 0 | 0 | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ |

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| Vehicles | Position of vehicles in track | Case number | $A_{1,A}$ | $A_{1,B}$ | $A_{2,A}$ | $A_{2,B}$ | $A_{3,A}$ | $A_{3,B}$ | $A_{4,A}$ | $A_{4,B}$ | $A_{5,A}$ | $A_{5,B}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| designated as a "motor" bogie and 1 trailing bogie or regarded as a "trailing" bogie |   | (16) | $-\frac{n_a}{a}$ | $-\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | 0 | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ |
| Vehicles with 2 trailing bogies or regarded as "trailing" bogies |   | (17) | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | 0 | 0 | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ |
| |   | (18) | $-\frac{n_a}{a}$ | $-\frac{n_a+a}{a}$ | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | 0 | 0 | $\frac{n_a+a}{a}$ | $\frac{n_a}{a}$ | $\frac{n_a+a}{a}$ |

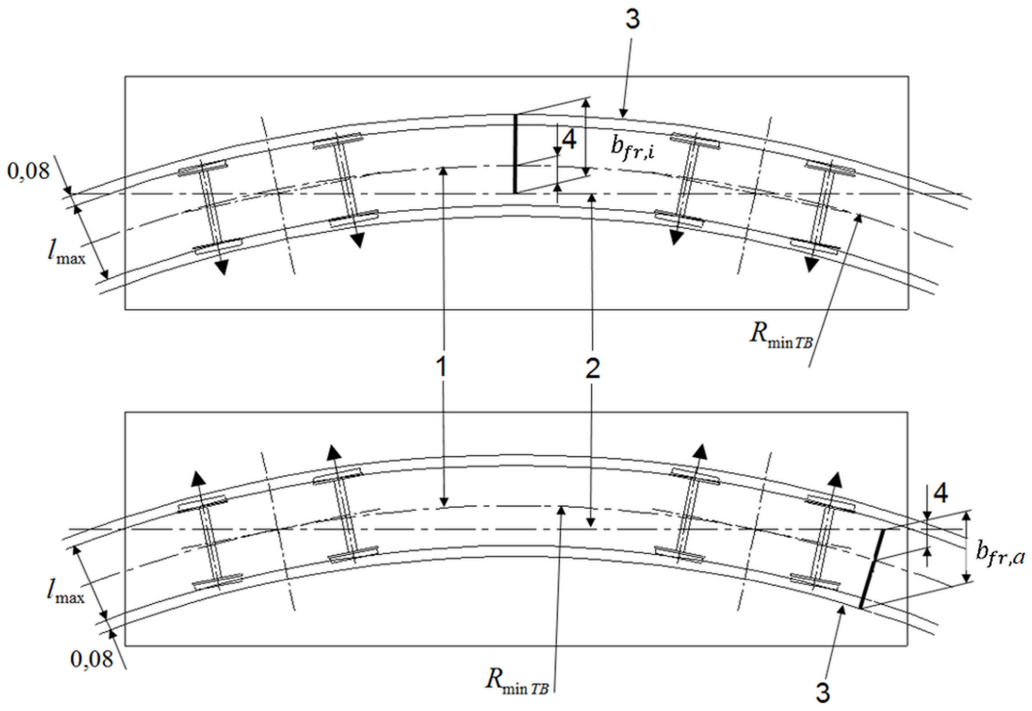
## A.3.4 Rules for bottom lines of gauge – shunting devices and contact ramps

### A.3.4.1 Use of shunting devices on curved tracks

Track brakes, when in an active position, and stopping devices, in particular the shunting device, can reach the height $h_{umin1}$ or $h_{umin2}$ (see Figure A.13) and may be installed on curves of radius $R_{minTB}$ (see Figure A.12).



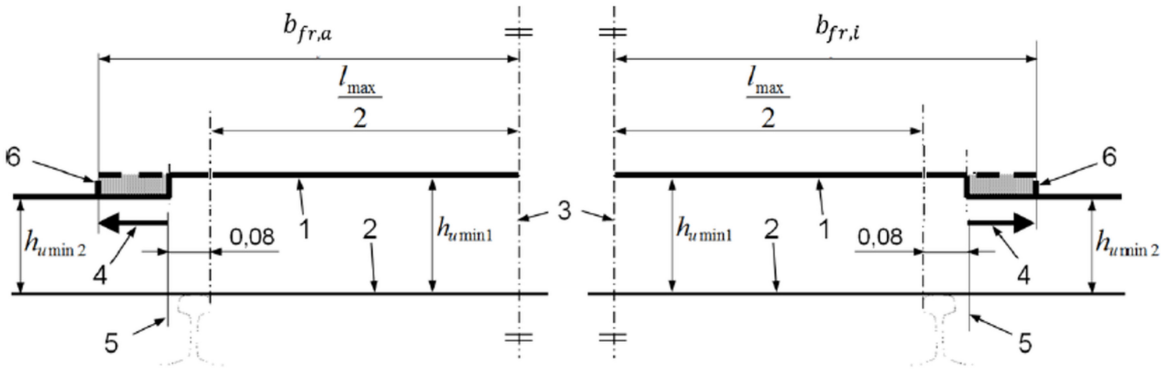
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**Key**

1 track centreline
2 centreline of vehicle
3 limit for drag shoes (or scotches)
4 increase (geometric overthrow + lateral displacement due to clearance between wheelsets and track)

**Figure A.12 — Distances $b_{fr,i}$ and $b_{fr,a}$ (top view)**




**Key**

1 reference profile
2 running plane
3 centreline of reference profile
4 increase (geometric overthrow + lateral displacement due to clearance between wheelsets and track)
5 limit for drag shoes (or scotches)
6 maximum construction gauge

**Figure A.13 — Distances $b_{fr,i}$ and $b_{fr,a}$ Cross section**



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It follows that the application limit for the $h_{umin1}$ or $h_{umin2}$ dimensions at a constant distance from the inner edge of the rail (0,080 m) is a variable distance $b_{fr,i}$ or $b_{fr,a}$ from the centreline of the vehicle, as shown in Figure A.13.

The formulae are:

— Formula (A.23) is applicable for the sections located between the end wheelsets or the bogie pivots:

$$b_{fr,i} = \frac{a \cdot n_{i,A} - n_{i,A}^2 + A_{1,A} \cdot \frac{p_A^2}{4} + A_{1,B} \cdot \frac{p_B^2}{4}}{2 \cdot R_{\min TB}} + A_{2,A} \cdot \frac{l_{max} - d_A}{2} + A_{2,B} \cdot \frac{l_{max} - d_B}{2} + 0,080 + \frac{l_{max}}{2} \qquad \text{(A.23)}$$

— Formula (A.24) is applicable for the sections located beyond the end wheelsets or the bogie pivots:

$$b_{fr,a} = \frac{a \cdot n_a + n_a^2 - A_{1,A} \cdot \frac{p_A^2}{4} + A_{1,B} \cdot \frac{p_B^2}{4}}{2 \cdot R_{\min TB}} + A_{2,A} \cdot \frac{l_{max} - d_A}{2} + A_{2,B} \cdot \frac{l_{max} - d_B}{2} + 0,080 + \frac{l_{max}}{2} \qquad \text{(A.24)}$$

NOTE 1 In the particular case involving the use of shunting devices, the influence of clearances $q + w$ can be considered as negligible.

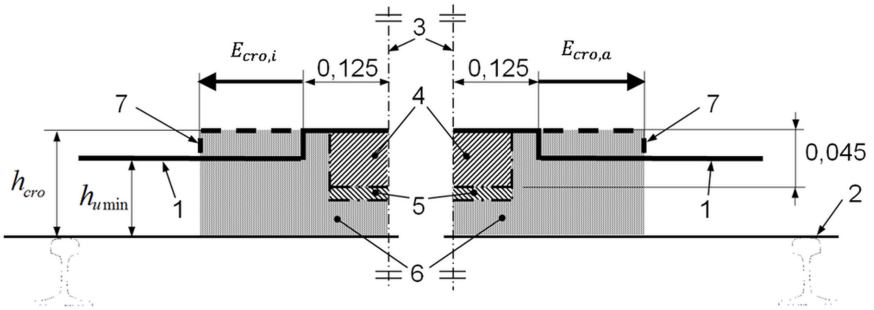
NOTE 2 Associated vertical rules are given in A.2.2.2.6.2.

NOTE 3 Values of coefficients " $A_n$ " are given in Tables A.2 to A.6.

### A.3.4.2 Contact ramps

For vehicles intended to operate on networks fitted with contact ramps, a free space shall be provided in the lower horizontal part of the reference profile at a height $h_{cro}$.

This free space shall contain only the brushes that shall come into contact with the ramps.




**Key**

1 reference profile
2 running plane
3 centreline of reference profile
4 zone for contact brushes when the vehicle is at a standstill
5 zone for contact brushes when the vehicle is running
6 zone reserved for contact ramps
7 maximum construction gauge

**Figure A.14 — Contact ramp zone**



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When the vehicle is at a standstill at design mass in working order for locomotives or design exceptional mass for other vehicles, as defined in EN 15663:2017+A1:2018, the contact brush may descend to a level 0,045 m down into the zone intended for installation of the contact ramps. Taking into account the flexible and deformable character of the contact brush, it is permitted for the contact brush to drop below this level only for the dynamic complementary displacement of the primary suspension.

The longitudinal position of the contact brush shall comply with the following rules:

1) brush mounted on bogie frame:

   a) sections located between wheelsets: no specific rule;

   b) Formula (A.25) is applicable for the sections located beyond wheelsets:

$$\frac{p \cdot n_a + n_a^2}{2 \cdot R_{cro}} + \frac{2 \cdot n_a + p}{p} \cdot \left( \frac{l_{max-d}}{2} + q \right) \leq 0,065 \qquad \text{(A.25)}$$

2) brush mounted under body frame of vehicle with independent wheelsets:

   a) Formula (A.26) is applicable for the sections located between wheelsets:

$$\frac{a \cdot n_i - n_i^2}{2 \cdot R_{cro}} + \frac{l_{max} - d}{2} + q \leq 0,065 \qquad \text{(A.26)}$$

   b) sections located beyond wheelsets: installation of brush is forbidden.

NOTE 1 Explanations about 0,065 m are given in prCEN/TR 15273-5:2023.

Vehicle parts likely to descend to less than $h_{cro}$ from the running plane on track without vertical curvature with vertical displacements as defined in A.2.2, shall not be located less than 0,125 m from the track centreline when the vehicle is installed on a curved track of radius $R_{cro}$ and track width $l_{max}$.

For parts under the bogies, the semi-width to be cleared in the contact ramp zone is fixed at 0,150 m.

The semi-width of the space for contact ramps below the vehicles considered shall exceed the corresponding semi-width of this space on the reference profile of the gauge, increased by the values $E_{cro,i}$ or $E_{cro,a}$.

The formulae are:

— Formula (A.27) is applicable for the sections located between the end wheelsets or the bogie pivots:

$$E_{cro,i} = \frac{a \cdot n_{i,A} - n_{i,A}^2 + A_{1,A} \cdot \frac{p_A^2}{4} + A_{1,B} \cdot \frac{p_B^2}{4}}{2 \cdot R} + A_{2,A} \cdot \frac{l_{max} - d_A}{2} + A_{2,B} \cdot \frac{l_{max} - d_B}{2} + A_{3,A} \cdot w_{i,(R_{cro}),A} + A_{3,B} \cdot w_{i,(R_{cro}),B} + A_{5,A} \cdot q_A + A_{5,B} \cdot q_B \qquad \text{(A.27)}$$

— Formula (A.28) is applicable for the sections located beyond the end wheelsets or the bogie pivots:



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$$E_{cro,a} = \frac{a \cdot n_a + n_a^2 - A_{1,A} \cdot \frac{p_A^2}{4} + A_{1,B} \cdot \frac{p_B^2}{4}}{2 \cdot R} + A_{2,A} \cdot \frac{l_{max} - d_A}{2} + A_{2,B} \cdot \frac{l_{max} - d_B}{2} + A_{3,A} \cdot w_{i,(R_{cro}),A} + A_{3,B} \cdot w_{i,(R_{cro}),B} + A_{4,A} \cdot w_{a,(R_{cro}),A} + A_{4,B} \cdot w_{a,(R_{cro}),B} + A_{5,A} \cdot q_A + A_{5,B} \cdot q_B \quad \text{(A.28)}$$

NOTE 2 Values of coefficients "$A_n$" are given in Tables A.3 to A.6.

The longitudinal position of the contact brush should also comply with the local regulation.

## A.4 Pantograph gauge verification and non-insulated devices on the vehicle's roof

### A.4.1 Pantograph gauge verification

#### A.4.1.1 General principles

For pantograph reference profile, basic data and horizontal projections – see prEN 15273-4:2023, Clause 8.

The verification calculation shall show that the pantograph movements to be verified are no greater than those agreed as standard for the rolling stock; the result is that the values of $P'_{o,i}$ and $P'_{o,a}$ (pantographs raised to $h'_o$ above running plane) and $P'_{u,i}$ and $P'_{u,a}$ (pantographs raised to $h'_u$ above running plane) shall be negative or zero applying the formulae given in A.4.1.2 and A.4.1.3.

a) Vehicles where the lateral clearances vary linearly according to 1/*R*.

   Two cases shall be analysed: the position of a vehicle operating along on a curve of minimum radius $R_{min}$ and the position on a straight track, $R = \infty$.

b) Vehicles where the lateral clearances vary nonlinearly according to 1/*R*.

In addition to operation along a straight track and on a curve radius $R_{min}$, the verification is carried out on the curve radius $R$ for which the variation of the clearance $w$ relative to 1/R presents a discontinuity (or more than one), e.g. a value of $R$ from which the variable bump stops begin to work.

If the lateral clearances vary according to the operational radius, in the following formulae, the maximum value $w_{i,(R)}$ at pivot level (real or theoretical) shall be taken for $P'_{o,i}$ and $P'_{u,i}$, and for $P'_{o,a}$ and $P'_{u,a}$ the value $w_{a,(R)}$ and the corresponding value $w_{i,(R)}$.

Pantographs are usually very close to the bogie centre, the following formulae only take into account parameters $p$, $q$, $d$ of the closest bogie to the pantograph. The values of coefficients "$A$" are given by Tables A.3 to A.6.

#### A.4.1.2 Formulae for a pantograph located between the end wheelsets or the bogie pivots (verification with the vehicle at a standstill on canted track)

Formula (A.29) and Formula (A.30) are applicable for the sections located between the end wheelsets or the bogie pivots:



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$$P'_{o,i} = \frac{a \cdot n_{i,A} - n_{i,A}^2 + \frac{p^2}{4}}{2 \cdot R} + q + A_{3,A} \cdot w_{i,(R),A} + A_{3,B} \cdot w_{i,(R),B} + \frac{s \cdot D'_0}{L} \cdot \left(h'_o - h_c\right) + \sqrt{t^2 + \tau^2 + \left[\theta \cdot \left(h'_o - h_c\right)\right]^2} + \left[\frac{s \cdot \left(D'_{max} - D'_0\right)}{L} \cdot \left(h'_o - h_c\right) - \frac{s'_0 \cdot \left(D'_{max} - D'_0\right)}{L} \cdot \left(h'_o - h'_{c0}\right)\right]_{>0} - \left(e_{p,o} + Abt_o\right) - S'_R \quad \text{(A.29)}$$

If $P'_{o,i} \leq 0$ the pantograph remains inside the gauge at its upper collecting point.

$$P'_{u,i} = \frac{a \cdot n_{i,A} - n_{i,A}^2 + \frac{p^2}{4}}{2 \cdot R} + q + A_{3,A} \cdot w_{i,(R),A} + A_{3,B} \cdot w_{i,(R),B} + \frac{s \cdot D'_0}{L} \cdot \left(h'_u - h_c\right) + \sqrt{t\left(\frac{h'_u - h_t}{h'_o - h_t}\right)^2 + \tau^2 + \left[\theta \cdot \left(h'_u - h_c\right)\right]^2} + \left[\frac{s \cdot \left(D'_{max} - D'_0\right)}{L} \cdot \left(h'_u - h_c\right) - \frac{s'_0 \cdot \left(D'_{max} - D'_0\right)}{L} \cdot \left(h'_u - h'_{c0}\right)\right]_{>0} - \left(e_{p,u} + Abt_u\right) - S'_R \quad \text{(A.30)}$$

If $P'_{u,i} \leq 0$ the pantograph remains inside the gauge at its lower collecting point.

### A.4.1.3 Formulae for a pantograph located beyond the end wheelsets or bogie pivots (verification of vehicle in running conditions on track with cant deficiency)

Formula (A.31) and Formula (A.32) are applicable for the sections located beyond the end wheelsets or bogie pivots:

$$P'_{o,a} = \frac{a \cdot n_a + n_a^2 - \frac{p^2}{4}}{2 \cdot R} + \frac{l_{max} - d}{2} \cdot \frac{2n_a}{a} + q \cdot \frac{2n_{a+a}}{a} + A_{3,A} \cdot w_{i,(R),A} + A_{3,B} \cdot w_{i,(R),B} + A_{4,B} \cdot w_{a,(R),A} + A_{4,B} \cdot w_{a,(R),B} + \frac{s \cdot I'_0}{L} \cdot \left(h'_o - h_c\right) + \sqrt{t^2 + \tau^2 + \left[\theta \cdot \left(h'_o - h_c\right)\right]^2} + \left[\frac{s \cdot \left(I'_{max} - I'_0\right)}{L} \cdot \left(h'_o - h_c\right) - \frac{s'_0 \cdot \left(I'_{max} - I'_0\right)}{L} \cdot \left(h'_o - h'_{c0}\right)\right]_{>0} - \left(e_{p,o} + Abt_o\right) - S'_R \quad \text{(A.31)}$$

If $P'_{o,a} \leq 0$ the pantograph remains inside the gauge at its upper collecting point.

$$P'_{u,a} = \frac{a \cdot n_a + n_a^2 - \frac{p^2}{4}}{2 \cdot R} + \frac{l_{max} - d}{2} \cdot \frac{2n_a}{a} + q \cdot \frac{2n_{a+a}}{a} + A_{3,A} \cdot w_{i,(R),A} + A_{3,B} \cdot w_{i,(R),B} + A_{4,B} \cdot w_{a,(R),A} + A_{4,B} \cdot w_{a,(R),B} + \frac{s \cdot I'_0}{L} \cdot \left(h'_u - h_c\right) + \sqrt{\left(t\frac{h'_u - h_t}{h'_o - h_t}\right)^2 + \tau^2 + \left[\theta \cdot \left(h'_u - h_c\right)\right]^2} + \left[\frac{s \cdot \left(I'_{max} - I'_0\right)}{L} \cdot \left(h'_u - h_c\right) - \frac{s'_0 \cdot \left(I'_{max} - I'_0\right)}{L} \cdot \left(h'_u - h'_{c0}\right)\right]_{>0} - \left(e_{p,u} + Abt_u\right) - S'_R \quad \text{(A.32)}$$

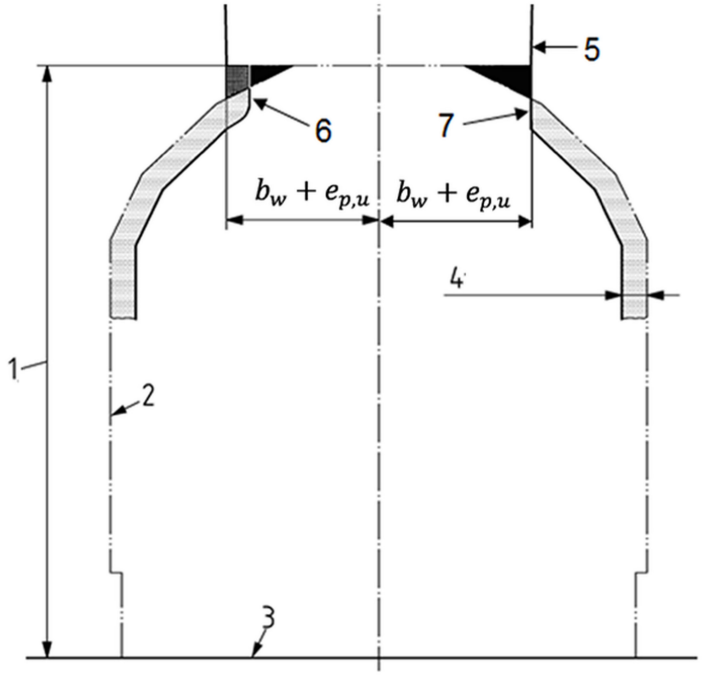
If $P'_{u,a} \leq 0$ the pantograph remains inside the gauge at its lower collecting point.



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## A.4.2 Pantographs in lowered position and non-insulated live parts on vehicle's roof

### A.4.2.1 Pantographs in lowered position and non-insulated live parts on vehicle's roof reference profile




**Key**

| | |
|---|---|
| 1 | height of the kinematic reference profile |
| 2 | kinematic reference profile |
| 3 | running plane |
| 4 | insulating distance according to voltage of power supply system $c_{elec}$ – see Table A.7 |
| 5 | pantograph reference profile |
| 6 | for pantograph with insulated horns – Infrastructure does not take into account insulating distance corresponding to the width of insulated horns $c_W$, so Rolling stock has to take it into account |
| 7 | for pantograph without insulated horns – In this case, Infrastructure Manager takes into account insulating distance |
| | Zones into which the non-insulated parts likely to remain live shall not penetrate |
| | "Special zones" – see A.4.2.3 |

**Figure A.15 — Pantographs in lowered position and non-insulated live parts on vehicle roof reference profile**

For insulating distance values see the Table A.7.



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**Table A.7 — Values for the insulating distance $c_{elec}$**

| Voltage system | Insulating distance m |
|---|---|
| 25 kV AC | 0,170 |
| 15 kV AC | 0,150 |
| 3 kV DC | 0,100 |
| 1,5 kV DC | 0,100 |
| 750 V | 0,100 |

#### A.4.2.2 Rules for non-insulated devices on the vehicle roof outside the pantograph reference profile

For all non-insulated devices on the vehicle roof outside the pantograph reference profile, the dimension of the maximum construction gauge shall be reduced by the insulating distance given in Table A.7.

#### A.4.2.3 Rules for devices on the vehicle roof and pantograph in lowered position inside pantograph reference profile

Without exceeding the height of the defined kinematic gauge reference profile, on electrified lines, with reference to Figure A.15, “special zones” may be used to define the width of the pantograph reference profile.

To maintain gauge interoperability, the width of these zones shall take into account the width of the narrowest pantograph head and therefore their semi-width is limited to the value $b_w$ of the smallest pantograph head – see EN 50367:2020.

Greater values may be used, but in this case the vehicle may not be compatible with all infrastructure of the required gauge.

On non-electrified lines, specific studies have to be done on the railway networks to use “special zones”.

All devices on the vehicle roof and the pantograph in the stowed position shall be arranged to comply both with the maximum construction gauge and the pantograph reference profile, reduced by the values $E_i$ or $E_a$ as defined following A.3 with specific lateral projection $S_R^{'}$ and basic data ($I_0^{'}$, $D_0^{'}$, $I_{max}^{'}$, $D_{max}^{'}$, $s_0^{'}$, $h_{c0}$) used for pantograph gauge verification, except for $z_{cin}$ calculated with Formula (A.33) and Formula (A.34).

$$z_{cin} = \left[\frac{s \cdot D_0^{'}}{L} + \theta\right](h - h_c) + \left[\frac{s \cdot \left(D_{max}^{'} - D_0^{'}\right)}{L} \cdot (h - h_c) - \frac{s'_0 \cdot \left(D_{max}^{'} - D_0^{'}\right)}{L} \cdot \left(h - h_{c0}^{'}\right)\right]_{>0} \quad \text{(A.33)}$$

Or

$$z_{cin} = \left[\frac{s \cdot I_0^{'}}{L} + \theta\right](h - h_c) + \left[\frac{s \cdot \left(I_{max}^{'} - I_0^{'}\right)}{L} \cdot (h - h_c) - \frac{s'_0 \cdot \left(I_{max}^{'} - I_0^{'}\right)}{L} \cdot \left(h - h_{c0}^{'}\right)\right]_{>0} \quad \text{(A.34)}$$

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If the collecting pantograph head has insulated horns, allowances shall be taken into account also for non-insulated parts likely to remain live, including another pantograph in the lowered position, if any. Otherwise insulating allowances will not be taken into account – see Figure A.14.

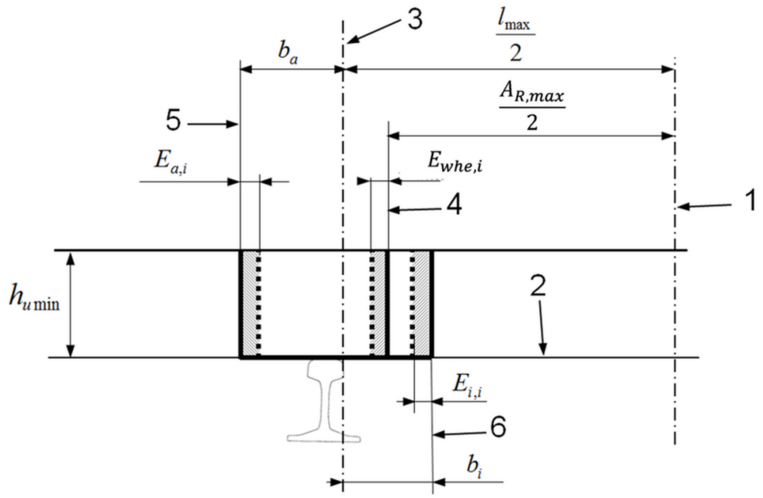
## A.5 Wheel zone

This subclause considers parts mounted on bogies or on vehicles fitted with independent wheelsets which may descend below $h_{umin}$ and for which, a risk of contact with the infrastructure is not acceptable.

Taking into account the lateral displacements of the following parts, their dimensions shall:

— on the inside of the wheels not be less than, the half maximum distance between internal surfaces of wheels $\frac{A_{R,max}}{2}$ increased by $E_{whe,i}$ or $E_{whe,a}$ or the limit position of the wheel (see Figure A.16 and Figure A.17) increased by $E_{i,i}$ or $E_{a,a}$.

— on the outside of the wheels not larger than the limit position of the wheel (see Figure A.16 and Figure A.17) reduced by $E_{a,i}$ or $E_{a,a}$.




**Key**

1 centreline of reference profile
2 running plane
3 internal face of the rail
4 wheel internal surface
5 limit position of the wheel outer face and of the parts associated with the wheel
6 limit position of the wheel internal surface when the opposite wheel is in flange contact

**Figure A.16 — Wheel zone – sections located between wheelsets**



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