

Railway applications — Gauges

Part 2: Rolling stock gauge

ICS 45.020

National foreword

This British Standard is the UK implementation of EN 15273-2:2009.

The UK participation in its preparation was entrusted by Technical Committee RAE/1, Railway applications, to Subcommittee RAE/001/-/12, Railway applications – Gauging.

A list of organizations represented on this committee can be obtained on request to its secretary.

Gauging practices used in Great Britain are documented in Railway Group Standards, published for the GB main line railway industry by Rail Safety and Standards Board Limited (RSSB), www.rssb.co.uk. Railway Group Standards are freely available from www.rgsonline.co.uk.

The gauging practices used in Great Britain diverge significantly from the International Union of Railways (UIC) gauging practices used in much of the rest of Europe. Although BS EN 15273 Railway applications – Gauges defines a number of different gauging methodologies and applications, the underlying philosophy is that of the UIC method of gauging, which depends on the use of reference profiles. It should be noted, therefore, that BS EN 15273 and Railway Group Standards sometimes use the same terms, but with different meanings. The terminology used in one cannot be used to interpret the requirements of the other.

This part of BS EN 15273 includes a number of gauges specifically intended for use in Great Britain. However, current UK definitions of standard vehicle gauges specifically intended for use in Great Britain, with application rules for infrastructure and rolling stock, are set out in the relevant Railway Group Standard.

National Annex NA gives the definitions used in Great Britain for some of the key terms used in BS EN 15273.

Mandatory European requirements relating to rolling stock gauges are set out in the High Speed Rolling Stock Technical Specification for Interoperability (HS RST TSI), adopted in 2007, and the Conventional Rail Locomotive and Passenger Technical Specification for Interoperability (CR LOC+PAS TSI), expected to be adopted in 2011. Both TSIs contain GB specific cases relating to gauging requirements. These should be read in conjunction with BS EN 15273.

Except where a decision has been made to adopt standard European gauges, and to use the associated gauging techniques documented in BS EN 15273, the gauges and gauging practices used on the GB main line railway should continue to be those documented in Railway Group Standards.

BS EN 15273 should be used where a decision has been made to adopt standard European gauges, and to use the associated gauging techniques.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Foreword

This document (EN 15273-2:2009) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and/or CENELEC shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(2008/57/EC.

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

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Introduction

EN 15273 comprises three parts, namely

- EN 15273-1 that covers general definitions and the rules applicable to rolling stock and structure gauges;
- EN 15273-2 that gives the rules for calculating the rolling stock gauges and the associated rules for the various profiles;
- EN 15273-3 that gives the rules for the structure gauges. It explains the parameters concerned and gives a possible methodology for determining the structure gauges and the distances between centres of the tracks.

1 Scope

This document is applicable by the authorities involved in all types of railway operation.

This European Standard is applicable to new designs, to modifications and to the checking of the gauge for vehicles already in use.

The application of the rules of this European Standard makes it possible to determine the maximum dimensions of vehicles related to the structures.

The rules given in this standard are not applicable to vehicles guided by a single rail.

This European Standard contains:

- the associated rules for all the gauges for rolling stock;
- the requirements for composing the technical gauge report to submit to the Acceptance Authority in order to confirm vehicle conformity to this standard;
- the requirements for maintaining the vehicle characteristics influencing gauging throughout its operational life.

2 Normative references

The following referenced documents are indispensable for the application 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 12299, *Railway applications — Ride comfort for passengers — Measurement and evaluation*

EN 12663, *Railway applications — Structural requirements of railway vehicle bodies*

EN 14363:2005, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests*

EN 15273-1:2009, *Railway applications — Gauges — Part 1: General — Common rules for infrastructure and rolling stock*

EN 15273-3:2009, *Railway applications — Gauges — Part 3: Structure gauges*

EN 50119, *Railway applications — Fixed installations — Electric traction overhead contact lines*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply to differentiate between the various types of vehicle:

3.1

empty vehicle

definition according to EN 12663

3.2

vehicle construction tolerance

tolerance on the external nominal dimensions of the vehicle, as specified in the design documents

3.3

$[\dots]_{>0}$

value to be considered only when it is positive; negative values are regarded as being equal to zero

3.4

$|\dots|$

mathematical absolute value

4 Symbols and abbreviations

For the purposes of this European Standard, the symbols and abbreviations given in Table 1 are applicable.

Table 1 — Symbols and abbreviations

Symbol	Designation	Unit	Symbol number
a	Distance between end axles of vehicles not fitted with bogies or between bogie centres	m	1.001
A	Coefficient of displacement		1.003
b	Semi-width or distance parallel to the running surface, relative to the centreline of the track or of the vehicle	m	1.007
b_G	Semi-spacing of side bearers	m	1.017
b_w	Semi-width of the pantograph head	m	1.033
b_1	Semi-width of the primary suspension springs	m	2.001
b_2	Semi-width of the secondary suspension springs	m	2.002
C	Roll centre		1.035

Table 1 (continued)

Symbol	Designation	Unit	Symbol number
d	Dimension over wheel flanges	m	1.037
dg_a	Geometric overthrow of the vehicle on the outside of the curve	m	1.038
dg_{av}	Vertical geometric overthrow of the vehicle on the outside of the curve	m	1.040
dg_i	Geometric overthrow of the vehicle on the inside of the curve	m	1.041
dg_{iv}	Vertical geometric overthrow on the inside of the curve	m	1.043
D	Cant	m	1.044
Dpl	Transverse displacement	m	1.051
e_a	Vertical reduction on the outside of the curve	m	1.065
e_i	Vertical reduction on the inside of the curve	m	1.066
e_p	Offset of the pantograph due to the vehicle characteristics	m	1.067
e_{po}	Offset of the pantograph at the upper verification point	m	1.068
e_{pu}	Offset of the pantograph at the lower verification point	m	1.071
E	Transverse reduction relative to the reference profile	m	1.074
E_a	Transverse reduction relative to the reference profile for cross-sections beyond the axles or beyond the bogie centres	m	1.075
E_i	Transverse reduction relative to the reference profile for cross-sections between the axles or between the bogie centres	m	1.076
f	Vertical sag	m	2.003
G	Centre of gravity of the body		1.087
h	Height in relation to the running surface	m	1.088
h_c	Roll centre height	m	1.091
h_t	Installation height of the lower pantograph joint relative to the running surface	m	2.004
I	Cant deficiency	m	1.107
I'_c	Intermediate cant deficiency value between 0 and I_c	m	1.108
I'_p	Intermediate cant deficiency value taken into account for tilting body vehicles	m	1.109
I_c	Maximum cant deficiency used by the infrastructure manager for his routes	m	1.110
I_{max}	Maximum cant deficiency	m	1.114
I_p	Cant deficiency of tilting body vehicles	m	1.117

Table 1 (continued)

Symbol	Designation	Unit	Symbol number
j	Minimum vertical reference clearances at the level of the side bearers	m	1.119
j'_a	Additional transverse clearances, towards the outside of the curve, relative to those of the reference vehicle	m	1.120
j'_i	Additional transverse clearances, towards the inside of the curve, relative to those of the reference vehicle	m	1.121
J	Actual vertical clearance at the level of the side bearers	m	1.122
l	Track gauge, distance between the rail running edges	m	1.126
$l_{\max}$	Maximum track gauge	m	1.130
L	Standard distance between the centrelines of the rails of the same track	m	1.134
n	Distance from the section under consideration to the adjacent end axle or to the closest pivot	m	1.157
n_a	n for the sections outside the axles or bogie centres	m	1.158
n_i	n for the sections between the axles or bogie centres	m	1.160
n_{μ}	Distance from the section under consideration to the motor bogie centre of motor coaches	m	2.005
p	Bogie wheelbase	m	1.163
p'	Carrying bogie wheelbase of motor coaches	m	2.006
P_o	Reduction at the upper verification point of the pantographs	m	1.164
P_{oa}	Reduction at the upper verification point (6,5 m) of the pantographs beyond the bogie centres	m	1.165
P_{oi}	Reduction at the upper verification point (6,5 m) of the pantographs between the bogie centres	m	1.166
P_u	Reduction at the lower verification point (5,0 m) of the pantographs	m	1.169
P_{ua}	Reduction at the lower verification point (5,0 m) of the pantographs beyond the bogie centres	m	1.170
P_{ui}	Reduction at the lower verification point (5,0 m) of the pantographs between the bogie centres	m	1.171
q	Transverse clearance between wheelset and bogie frame, or wheelset and body for vehicles not fitted with bogies	m	1.172
Q	Displacement due to the complete quasi-static roll	m	1.176
R	Horizontal curve radius	m	1.178
$R_{\min}$	Minimum curve radius	m	1.182

Table 1 (continued)

Symbol	Designation	Unit	Symbol number
R_p	Radius corresponding to the maximum roll of a tilting body vehicle	m	1.183
R_v	Vertical curve radius	m	1.185
S	Flexibility coefficient		1.187
s_0	Flexibility coefficient taken into account in the agreement between the vehicle and the infrastructure		1.188
s_n	Flexibility coefficient of the pantograph carrying structure		2.007
s'_0	Flexibility coefficient taken into account in the agreement between the vehicle and the infrastructure for the pantograph gauge		1.189
S	Allowed additional overthrow	m	1.192
S_0	Standard value of additional overthrow linked to the reference profile	m	1.193
T	Pantograph flexibility coefficient	m	1.209
v	Vehicle speed	m/s	1.219
V	Vehicle speed	km/h	1.220
V'_c	Intermediate value of the standard train speed	km/h	1.221
V'_p	Intermediate value of the tilting train speed	km/h	1.222
W	Transverse clearance between bogie and body	m	1.228
w_∞	Transverse clearance between bogie and body on a straight track	m	2.008
w_i	Transverse clearance between bogie and body on the inside of the curve	m	2.009
w_a	Transverse clearance between bogie and body on the outside of the curve	m	2.010
$w_{a(R)}$	Transverse clearance between bogie and body towards the outside of the curve varying as a function of the track curve radius	m	1.230
$w_{i(R)}$	Transverse clearance between bogie and body towards the inside of the curve varying as a function of the track curve radius	m	1.231
x	Distance taken into account from the point of origin O for the calculation of the swept envelope	m	1.233
x_a	Additional reduction for long vehicles beyond the bogie centres	m	2.011
x_i	Additional reduction for long vehicles between the bogie centres	m	2.012
y	Distance between the theoretical centre and the geometric centre of the bogie	m	2.013

Table 1 (continued)

Symbol	Designation	Unit	Symbol number
z	Part of the quasi-static roll taken into account by the vehicle	m	1.234
z'	Difference between the transverse roll based on the calculation and the actual roll of the upper verification point of the pantograph	m	1.235
z''	Difference between the transverse roll based on the calculation and the actual roll of the lower verification point of the pantograph	m	1.236
z_{kin}	Quasi-static roll of the vehicle with regard to the kinematic gauge	m	1.238
z_p	Term z_{kin} determined for tilting body vehicles	m	2.014
α	Additional angle of roll of the body due to the clearance to the side bearers	°	1.242
α'	Angle of the inclined part of the pantograph head in relation to the horizontal	°	1.244
α''	Angle made by the link span between the quayside and the ferry	°	2.015
γ	Centrifugal acceleration	m/s ²	1.247
Δ_a	Fixed term corresponding to: $n_a (a + n_a) - \frac{p^2}{4}$	m ²	1.250
Δ_i	Fixed term corresponding to: $n_i (a - n_i) + \frac{p^2}{4}$	m ²	1.254
δ	Angle of roll of the canted track	°	1.255
λ	Angle made by the straight line joining the centre of gravity at the roll centre with the vertical	°	1.279
μ	Rail-wheel adhesion coefficient		2.016
η	Angle of roll of the vehicle relative to the running surface	°	1.280
η_0	Angle of dissymmetry of a vehicle due to construction tolerances, to suspension adjustment and to unequal load distributions	°	1.281
θ	Angle resulting from the suspension adjustment tolerances	radian	1.284
τ	Pantograph construction and installation tolerance	m	1.286
NOTE w'_{∞} , w'_a , w'_i , $w'_a(R)$ and $w'_i(R)$ have the same meaning for the carrying bogies of motor coaches.			

5 Common requirements

- a) it is mandatory to respect the association specified in each gauge between its profile and its associated rules;
- b) even though a vehicle does not or does not totally meet the requirements of this standard, it can be approved for operation with limitations. It is not then compatible with all the Infrastructures cleared for the same name gauge. Although the general framework is that of the TSI gauges, it is possible that the vehicle may not meet the interoperability requirements from the gauge point of view;
- c) where the vehicle is intended to be operated separately or in multiples, it shall meet the requirements of this document both individually and when forming a part of a train. Where the vehicle may be coupled permanently, this unit shall also meet the requirements of this standard;
- d) the vehicle characteristics that influence the gauge shall be maintained throughout the operational life of the vehicle and 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);
- e) wear limits and tolerances of all parts, equipment and systems influencing dynamic movements of the vehicle shall be included in the documents provided by the manufacturer for approving the use of the vehicle (see Annex Q).

5.1 Static and kinematic gauges

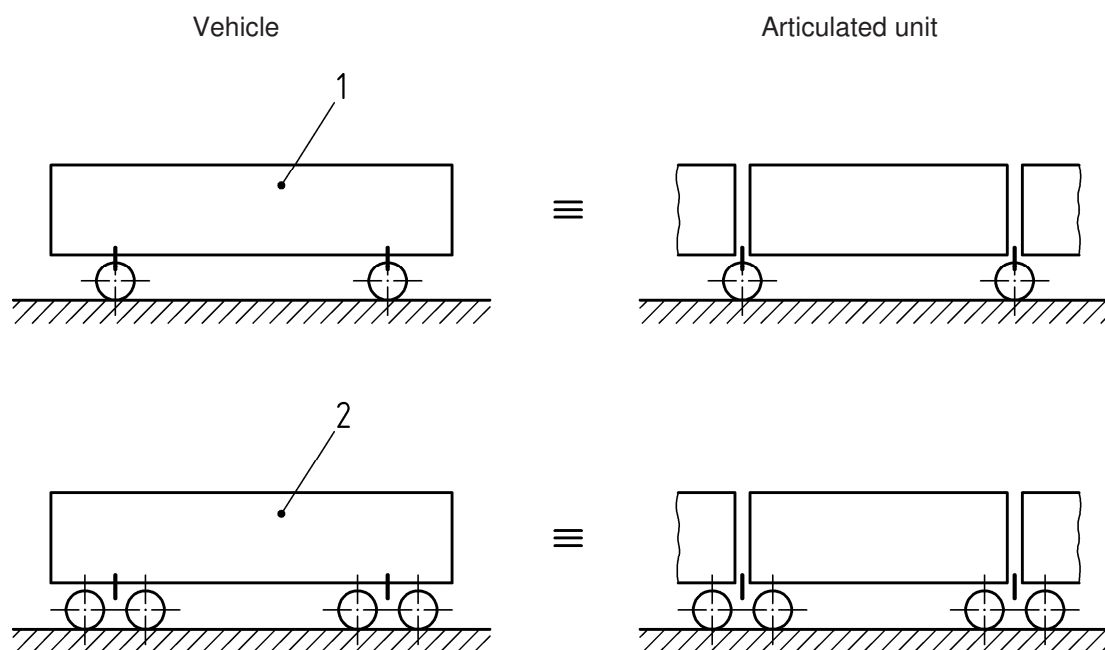
5.1.1 Description of the calculation method

Taking into account the transverse displacements of vehicles (specified in the associated rules for each gauge), the half-widths of the vehicles considered shall not exceed the corresponding half-width of the reference profile of the gauge, reduced by the values E_i or E_a calculated by applying the formulae given in this standard

5.1.2 Applicability of static and kinematic gauges depending on running gear of the vehicle

The static and kinematic gauges given in this standard are generally applicable to vehicles having the following running gear:

- a) vehicles not fitted with bogies with the body suspended on two axles. In the case of vehicles with bodies suspended on a number of different axles, it will be necessary to adapt the formulae to the actual geometric conditions;
- b) bogie vehicles with the body suspended on two bogies with two axles. In the case of vehicles with more than two bogies or fitted with bogies with more than two axles, it will be necessary to adapt the formulae to the actual geometric conditions;
- c) articulated unit: Figure 1 illustrates the calculation equivalence between non-bogie and bogie vehicles with symmetrical articulated units.



Key

- 1 2-axle
- 2 2-bogie

Figure 1 — Correspondence between separate vehicles and articulated units

Formulae given in this standard for static and kinematic gauges will not apply to other kinds of articulated units. The user will have to determine new formulae suitable for the actual geometric configurations.

5.1.3 Limitations for the use of static gauges

The use of static gauges is allowed only if the flexibility coefficient of the vehicle is less than the limit value as indicated in the associated rules for each static gauge (0,2 for G1, 0,3 for GA, GB, GB1, GB2 and GC etc.).

If the flexibility coefficient of the vehicle is greater than the limit value, it is mandatory to use other gauges, kinematic or dynamic, that take into account the extra inclination in respect to maximum values allowed for static gauges.

5.1.4 Requirements for use of kinematic gauges

- a) the formulae specified in each kinematic gauge shall be applied by introducing all the "worst case" parameters, i.e. with their maximum values (e.g. clearances, transverse and vertical displacements etc.);
- b) if, as a departure from the above point, a vehicle is designed using one or several parameters with their optimized value, the gauge documents file shall be submitted to the authority 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 infrastructures even if they fit the gauge of the same name.

If the vehicle examined does not completely meet the requirements of this standard, each case shall be documented to evaluate the effects and the gauge documents will have to be approved by the authority for gauging acceptance;

- c) kinematic gauges apply also to open wagons plus load units. 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 "load + wagon" unit can be regarded as a current type wagon;

- d) 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.

Measurement of the flexibility coefficient: EN 14363 explains the procedure for measuring the flexibility coefficient of a vehicle. This shall be adopted to meet the requirements of this standard.

5.1.5 Dimensional tolerances on vehicles

These tolerances are the differences between the nominal dimensional values and the values that construction technology actually allows to be attained.

The dimensions of finished vehicles shall remain within the maximum construction gauge of the vehicle.

For kinematic gauges covered by this standard, a part of vehicle tolerances can be ignored, up to:

- 0,01 m on the heights of upper and lower parts;
- 0,005 on transverse dimensions.

This allowance cannot be adopted to increase the nominal dimensions of the vehicles systematically.

The vehicle construction tolerances shall be specified in a dimensional specification (see Annex Q).

5.2 Dynamic methods

5.2.1 General principles

Safe operation of rolling stock on a railway network calls for the maintenance of adequate clearances between the vehicles and the adjacent infrastructure and between vehicles on adjacent tracks.

These clearances are obtained by subtracting from the infrastructure and other structures situated along the tracks the dynamic gauge and the distance between this and the structures.

This standard contains:

- a) a list of main reference profiles for the dynamic method existing in Europe together with their associated rules to calculate the maximum dimensions for rolling stock;
- b) the rules associated with the absolute method to calculate maximum dimensions for rolling stock.

5.2.2 Dynamic method based on a reference profile

A dynamic reference profile is a given general cross-section that the vehicles shall not exceed under specified conditions.

A vehicle swept envelope shall be calculated defining the maximum vehicle space to be occupied under normal service and fault conditions. This envelope shall remain within the dynamic reference profile on networks where the vehicle is required to operate.

The gauging methodology according to this standard describes two different ways of calculating the vehicle movements.

1) Movement calculation by geometric formulae:

Geometric formulae generate extreme movement data for selected cases and cross-sections in order to enable a preliminary vehicle sizing or a simplified gauging procedure.

2) Movement calculation by simulation:

Dynamic simulations generate a matrix of extreme vehicle movement data relative to the track centreline for combinations of curve radii and cant deficiency or excess. Movements are calculated for each vehicle of the train in each load/suspension condition by generating time-dependent data for significant points at selected cross-sections. The movements of these points shall be statistically assessed according to the method specific to each dynamic gauge.

Whatever calculation method is selected for the vehicle movements, it will be possible to include the effects mentioned below in the calculations or to add them to the calculated movements:

- nominal dimensions of the vehicle;
- geometric overthrow on curves (in the horizontal plane or in the vertical plane);
- vehicle tolerances and maintenance limits;
- excessive dissymmetry of the vehicle inclination ($\eta_0 > 1^\circ$);
- deflection under load;
- suspension displacement and wear;
- wheel radius differences between bogies or axles;
- adjustment devices to compensate for varying wheel diameters as well as suspension displacement and wear;
- pantograph flexibility.

Finally, the vehicle swept envelope is checked against the corresponding dynamic reference profile.

Annex A (normative)

Gauge G1

A.1 General

A.1.1 Vehicle classes

In order to apply the correct formulae to each kind of vehicle, vehicles have been classified as follows:

- locomotive: traction unit equipped with motor bogies. They are not intended to carry passengers or goods.

NOTE 1 From the gauge point of view, powered non-bogie locomotives are considered to be equivalent to non-bogie wagons

- coach: trailer vehicle designed to carry passengers, equipped with carrying axles or bogies

NOTE 2 From the gauge point of view, non-bogie coaches are considered to be equivalent to non-bogie wagons

- van: trailer vehicle designed to carry goods, to be inserted in the composition of passenger trains.

NOTE 3 From the gauge point of view, non-bogie vans are considered to be equivalent to non-bogie wagons

- wagon: trailer vehicle designed to carry freight. In this standard, formulae relating to wagons with bogies refer to a body-bogie link ensured by a centre bearing and side-bearers.

- special wagons: wagons whose loading surface height above the rail 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.

NOTE 4 This classification has an influence on the downwards displacements to be taken into account in the gauge calculation. Special wagons do not meet all requirements for wagons, so they are subjected to various restrictions related to the gauge, such as the prohibition of running on certain marshalling humps or ferry embarkation ramps.

- motor coach: traction unit carrying passengers or goods, with one or two motor bogies.

NOTE 5 From the gauge point of view, non-bogie motor coaches are considered to be equivalent to non-bogie wagons

- vehicles without fixed bogie centres

NOTE 6 In the case of vehicles without fixed bogie centres, 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 a 150 m radius curve, the clearance effects being evenly distributed and the axles centred on the track: if y is the distance of the theoretical centre from the geometric centre of the bogie (an equal distance from the end axles), p^2 will be replaced by $(p^2 - y^2)$ and p'^2 by $(p'^2 - y^2)$ in the formulae.

A.1.2 Bogie classes

Bogies are classified as follows:

- motor bogie: bogie, the axles of which are considered as powered (adhesion coefficient $\mu \geq 0,2$);
- carrying bogie: bogie, the axles of which are not considered as powered (adhesion coefficient $\mu < 0,2$);
- mixed bogie: bogie with powered axle and carrying axle

The definition of the adhesion coefficient is given in the following subclause.

A.1.3 Rail-wheel adhesion coefficient

Adhesion coefficient is:

$$\mu = \sqrt{\left(\frac{F_w}{M_e}\right)^2 + \left(\frac{D}{1.5}\right)^2} = \sqrt{\left(\frac{F_w}{M_e}\right)^2 + 0.0045} \quad (\text{A.1})$$

Where:

F_w is the peripheral maximum traction force at wheel rim;

M_e is the axle load;

D is the cant, assumed as 0,1 m

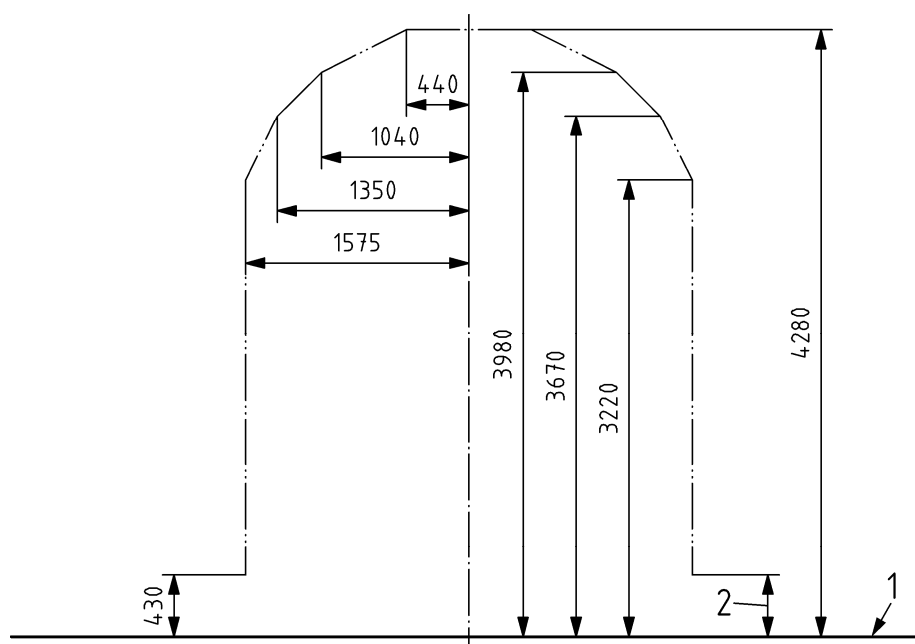
If $\mu < 0,2$, the bogie is considered to be the carrying type

If $\mu \geq 0,2$, the bogie is considered to be the motor type.

A.2 Static gauge G1

A.2.1 Reference profiles of upper and transverse parts

Dimensions in millimetres



Key

- 1 running surface
- 2 lower parts according to A.2.2

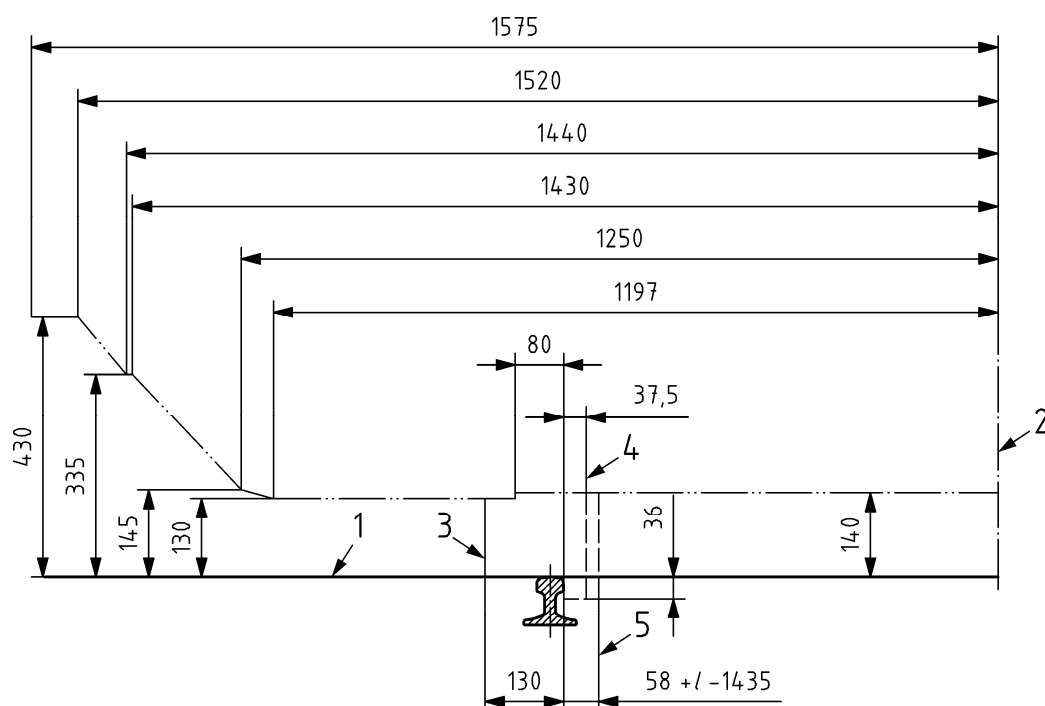
Figure A.1 — Reference profile of static gauge G1

A.2.2 Reference profiles of the lower part of static gauge G1

A.2.2.1 Static reference profile GIS1 of the lower parts

The GIS1 profile is the lower limit of vehicles passing over marshalling humps, rail brakes or other shunting and stopping devices (see Figure A.2).

Dimensions in millimetres



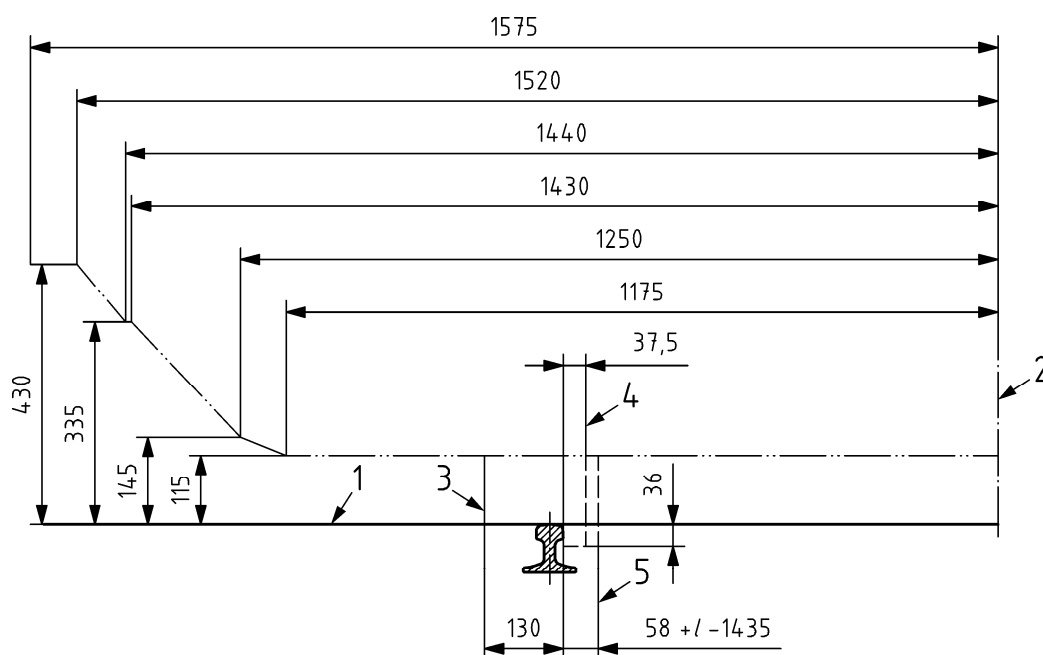
Key

- 1 running surface
- 2 reference profile centreline
- 3 limit position of the outside surface of the wheel
- 4 theoretical maximum width of the flange profile, taking into account the possible angle of the wheelsets on the track
- 5 effective position of the inside surface of the tyre when the opposite wheel is in flange contact

Figure A.2 — Reference profile GIS1 of lower parts

A.2.2.2 Static reference profile GIS2 of the lower parts

The GIS2 profile is the lower limit of the special low-floor wagons not passing over marshalling humps or activated rail brakes (see Figure A.3).



Key

- 1 running surface
- 2 reference profile centreline
- 3 limit position of the outside surface of the wheel
- 4 theoretical maximum width of the flange profile, taking into account the possible angle of the wheelsets on the track
- 5 effective position of the inside surface of the tyre when the opposite wheel is in flange contact

Figure A.3 — Reference profile GIS2 of lower parts of static gauge G1 for special low floor wagons

A.2.3 Rules associated with static gauge G1

A.2.3.1 Maximum flexibility coefficient of the vehicle

The static gauge may be used as long as the flexibility coefficient of the vehicle does not exceed 0,2. Otherwise, a kinematic or dynamic gauge has to be used.

A.2.3.2 Vertical downwards displacements

The vertical displacements to be taken into account to determine the minimum height of parts situated up to 0,43 m above the running surface are:

- wear of wheels and of suspension components;
- total displacement (bottoming) of the suspension.

A.2.4 Reduction formulae

A.2.4.1 Sections between the end axles or the bogie centres

$$E_i = \left[\frac{\Delta_i}{500} + \frac{1,465 - d}{2} + q + w + [x_i]_{>0} - 0,075 \right]_{>0} \quad (\text{A.2})$$

where $\Delta_i = 7,5$ if $\left(an_i - n_i^2 + \frac{p^2}{4} \right) \leq 7,5$ or $\Delta_i = \left(an_i - n_i^2 + \frac{p^2}{4} \right)$ if this quantity $> 7,5$

and

$$x_i = \frac{1}{750} \left(an_i - n_i^2 + \frac{p^2}{4} - 100 \right) \quad (\text{A.3})$$

A.2.4.2 Sections beyond the end axles or the bogie centres

$$E_a = \left[\frac{\Delta_a}{500} + \left(\frac{1,465 - d}{2} + q + w \right) \frac{2n_a + a}{a} + [x_a]_{>0} - 0,075 \right]_{>0} \quad (\text{A.4})$$

where $\Delta_a = 7,5$ if $\left(a \cdot n_a + n_a^2 - \frac{p^2}{4} \right) \leq 7,5$ or $\Delta_a = \left(a \cdot n_a + n_a^2 - \frac{p^2}{4} \right)$ if this quantity $> 7,5$

and

$$x_a = \frac{1}{750} \left(a \cdot n_a + n_a^2 - \frac{p^2}{4} - 120 \right) \quad (\text{A.5})$$

A.3 Kinematic gauge G1

A.3.1 General

Gauge G1 is the gauge used for the railway infrastructure of most of continental Europe.

It is divided into two parts:

- upper part 400 mm above the running surface, common to all vehicles;
- lower part from a point 400 mm and less from the running surface. This part is different according to whether the vehicles have to run over rail brakes and other activated marshalling and stopping devices or not (part below 130 mm).

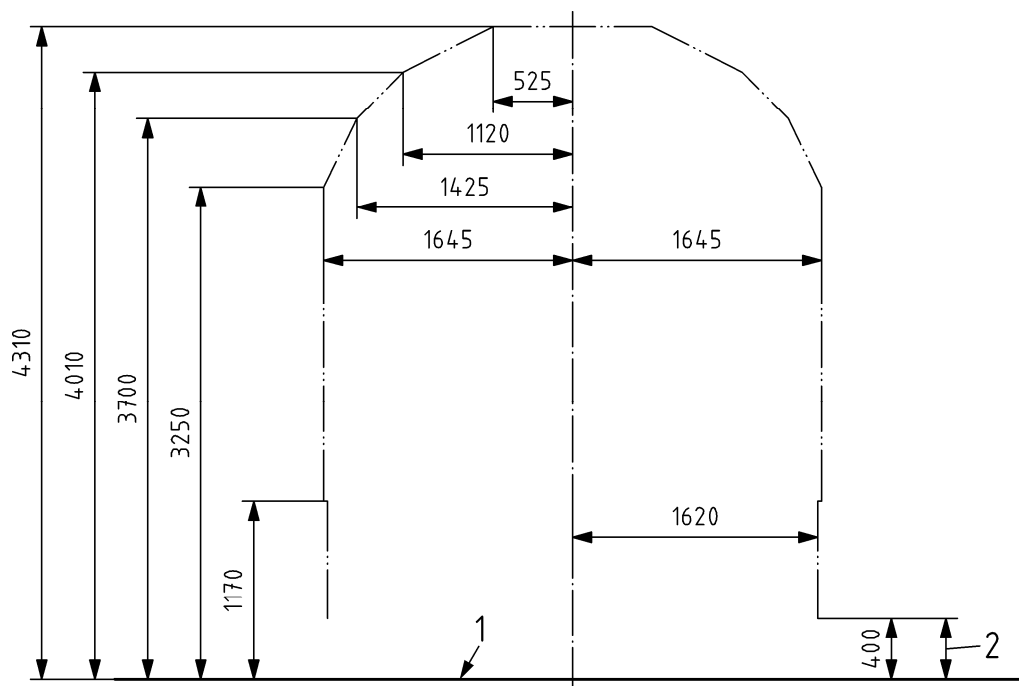
With regard to the part below 130 mm, it is different according to the type of vehicle.

Loaded coaches shall meet the rules of profile G1C2 when they run on a track not vertically curved.

Vans and wagons, either loaded or empty, shall comply with profile G1C1.

A.3.2 Reference profiles of the upper and transverse parts of gauge G1

Dimensions in millimetres



Key

- 1 running surface
- 2 lower parts of the profile according to A.3.3

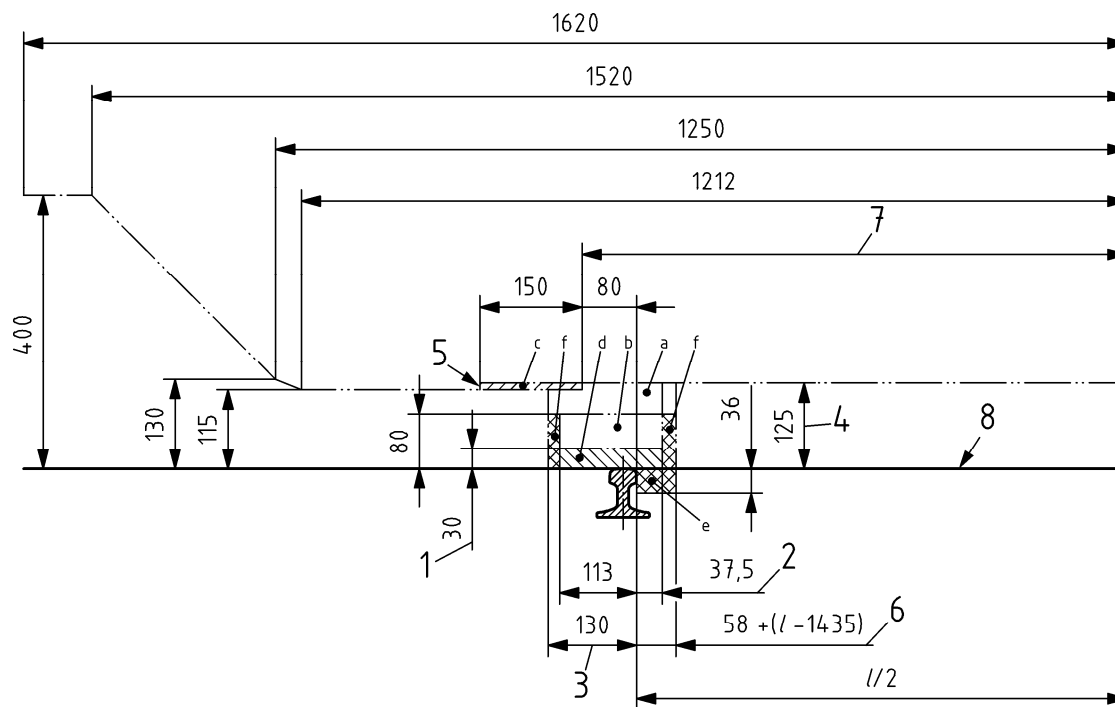
Figure A.4 — Reference profile of kinematic gauge G1

A.3.3 Reference profiles of the lower part of kinematic gauge G1

A.3.3.1 Reference profile G1C1

G1C1: profile of the lower part at 130 mm for vehicles able to pass over marshalling humps, rail brakes and other activated shunting and stopping devices (see Figure A.5).

Dimensions in millimetres



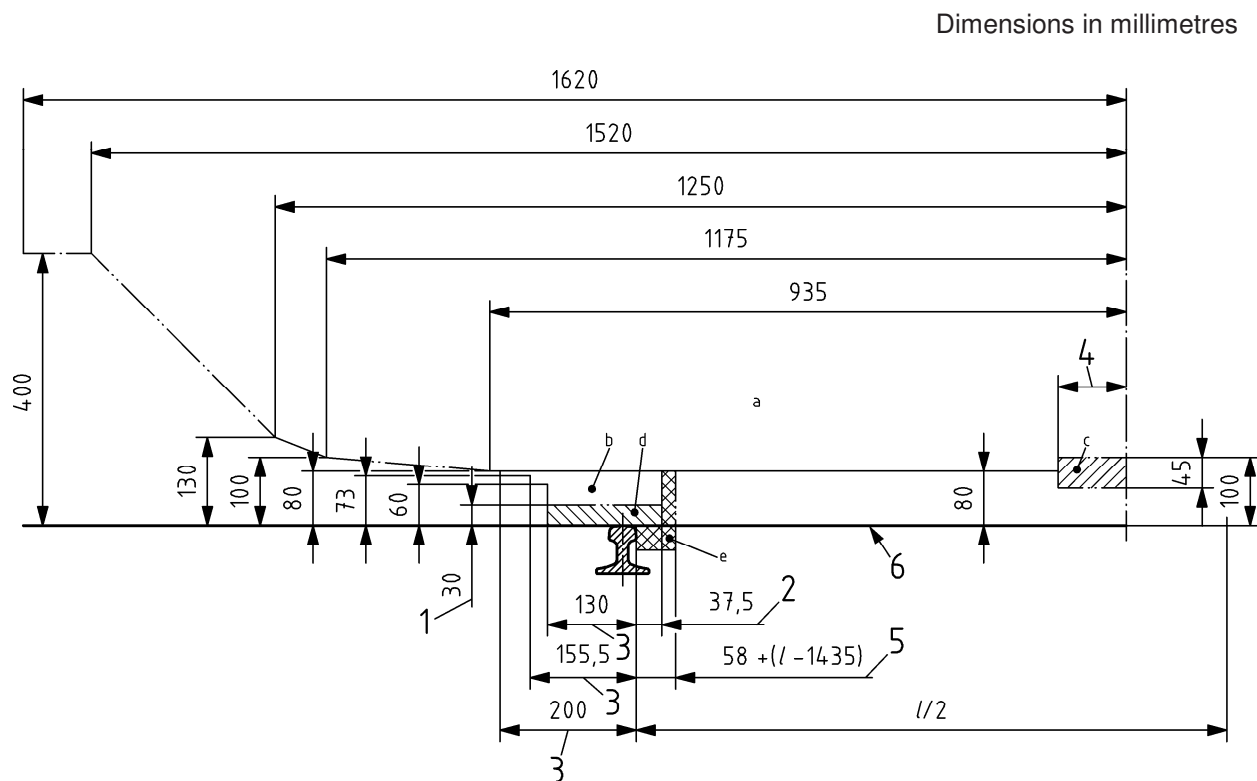
Key

- a zone for parts away from the wheels
 - b zone for parts in the immediate proximity of the wheels
 - c zone for retraction of standardized retarders
 - d zone for wheels and parts coming into contact with the rails
 - e zone occupied exclusively by the wheels
 - f zone for rail brakes in released position
- 1 limit for parts located outside the end axles (e.g. guard-irons, sanders, etc) not to be exceeded for running over detonators. This limit may, however, be disregarded for parts located between the wheels, provided these parts remain within the wheel track
 - 2 theoretical maximum width of the flange profiles in the case of check rails
 - 3 effective limit position of the wheel outer face and of the parts associated with the wheel
 - 4 this dimension also shows the maximum height of standardized retarders used for scotching or slowing
 - 5 no rolling stock part shall penetrate this zone
 - 6 effective limit position of the inside surface of the wheel when the opposite wheel is in flange contact. This varies with track gauge widening
 - 7 widening for retraction of standardized retarders
 - 8 running surface

Figure A.5 — Reference profile GLC1 of lower part at 130mm

A.3.3.2 Reference profile GIC2

GIC2: profile of the lower part at 130 mm for vehicles that shall not pass over rail brakes and other activated shunting and stopping devices (see Figure A.6).



Key

- a zone for parts away from the wheels
- b zone for parts in the immediate proximity of the wheels
- c zone for contact ramp brushes
- d zone for wheels and other parts coming into contact with the rails
- e zone occupied exclusively by the wheels
- 1 limit for parts located outside the end axles (guard-irons, sanders, etc) not to be exceeded for running over detonators. This limit may, however, be disregarded for parts located between the wheels, provided these parts remain within the wheel track
- 2 theoretical maximum width of the flange profiles in the case of check rails
- 3 effective limit position of the wheel outer face and of the parts associated with the wheel
- 4 when the vehicle is in any position whatsoever on a curve of radius $R = 250$ m (minimum radius for contact ramp installation) and a track gauge of 1 465 mm, no part of the vehicle likely to descend to less than 0,1 m above the running surface, except for the contact brush, shall be less than 0,125 m from the track centre line. For parts located inside the bogies, this dimension is 0,15 m
- 5 effective limit position of the inside surface of the wheel when the opposite wheel is in flange contact. This dimension varies with track gauge widening
- 6 running surface

Figure A.6 — Reference profile GIC2 for the part lower than 130 mm

A.3.4 Determination of the vehicle heights

For the vehicle or for a given part, these displacements make it possible to determine a minimum height and a maximum height above the running surface; this is particularly the case for:

- parts located near the lower part of the gauge (lower parts);
- the step 1 170 mm from the running surface on the reference profile;
- parts located in the upper part of the vehicles.

A.3.4.1 Determination of the minimum heights above the running surface

The minimum heights above the running surface for parts located near the lower part of the gauge, 1 170 mm and below, are determined taking into account the vertical displacements described in the following subclauses.

A.3.4.1.1 Wear displacements

These displacements concern the following parts:

- wheels: maximum wear for all types of vehicles;
- miscellaneous parts: maximum wear - examples: side-bearers, brake rigging, etc, for all vehicles and for each special assembly;
- axle boxes: wear ignored.

A.3.4.1.2 Structure deformation displacement

- axles: sag ignored;
- bogie frame: sag ignored;
- body:
 - 1) twist: ignored,
 - 2) transverse bending: ignored,
 - 3) longitudinal sag: ignored for all vehicles except wagons for which the longitudinal sag has to be taken into account under the effect of a maximum load increased by 30 % to take into account dynamic stresses.

A.3.4.1.3 Suspension displacement

The primary and secondary suspensions are formed of various types of springs for which the deflections shall be taken into account:

- steel spring:
 - 1) deflection under static load;
 - 2) additional deflection under dynamic stress;
 - 3) deflection due to flexibility tolerances;

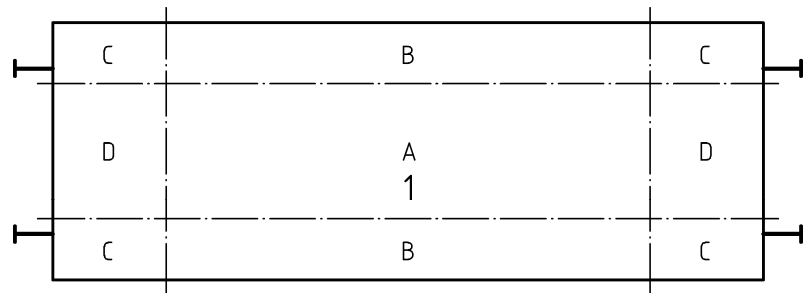
- rubber spring: same deflections as for steel springs;
- air spring: total deflection with air bags deflated (including back-up suspension when it exists).

The following suspension displacement conditions are to be taken into account depending on the type of vehicle:

- locomotives : suspension displacement with an overload of 30% of the sprung weight;
- coaches (empty): 30 mm fixed displacement;
- coaches and vans: displacement with an overload of 30% of the sprung weight (maximum load) or total displacement;
- wagons: total displacement (bottoming);
- special wagons: the displacement to be taken into account is that obtained with an overload of 30 % of the sprung weight; or that corresponding to total displacement (bottoming);
- motor coaches: displacement with an overload of 30 % overload of the sprung weight (maximum load) or total displacement.

A.3.4.1.4 Overall displacements to be taken into account to determine the minimum heights above the running surface

To define the displacement modes of the vehicle bodies, the cases in Figure A.7 are to be taken into account.



Key

- 1 support polygon

Figure A.7 — Body zones influencing displacements

For each zone A, B, C, D in Figure A.7, Table A.1 gives displacement values to take into account in the calculations.

Table A.1 — Displacement values

		Locomotives, motor coaches	coaches,	Wagons
	Suspension displacements	Aff		Aff
ZONE A	Clearances to the side bearers	-----		$J \frac{b}{b_G}$
	Wheel wear	Usr		Usr
	Body sag	0		Flc
	Gradient transition	See A.3.4.1.5		
	Suspension displacements	$Aff + 0.1 \cdot s \cdot (b - b_2)$ See Note		$Aff + \Delta Aff \frac{(b - b_2)}{2b_2}$
ZONE B	Clearances to side bearers	-----		$J \frac{b}{b_G}$
	Wheel wear	Usr		Usr
	Body sag	0		Flc
	Gradient transition	See A.3.4.1.5		
	Suspension displacements	$Aff + \Delta Aff \frac{n}{a} + 0.1 \cdot s \cdot (b - b_2)$		$Aff + \Delta Aff \frac{\sqrt{n^2 + (b - b_2)^2}}{\sqrt{a^2 + 4b_2^2}}$
ZONE C	Clearances to side bearers	-----		$J \frac{b}{b_G}$
	Wheel wear	$Usr + \Delta Usr \frac{n}{a}$		$Usr + \Delta Usr \frac{n}{a}$
	Body sag	0		Flc
	Gradient transition	See A.3.4.1.5		
	Suspension displacements	$Aff + \Delta Aff \frac{n}{a}$		$Aff + \Delta Aff \frac{n}{a}$
ZONE D	Clearances to side bearers	-----		$J \frac{b}{b_G}$
	Wheel wear	$Usr + \Delta Usr \frac{n}{a}$		$Usr + \Delta Usr \frac{n}{a}$
	Body sag	0		Flc
	Gradient transition	See A.3.4.1.5		

NOTE The flexibility coefficient value s covers the remaining suspension displacement possibilities. For instance, if A_{ff} is a bottoming displacement, s can be regarded as zero.

The notations used in Table A.1 are:

Aff: suspension displacement value, including spring tolerance as specified in A.3.4.1.3

ΔA_{ff} : difference in suspension displacement, in the longitudinal and transverse directions.

In the longitudinal direction, distance between the two bogies or axles; for the first displacement, under maximum static load and for the second displacement according to A.3.4.1.3. This second displacement corresponds to A_{ff} .

In the transverse direction, difference in displacement between the 2 rows of suspensions, for the first displacement under maximum static load and for the second displacement according to A.3.4.1.3. This second displacement corresponds to A_{ff} ;

U_{sr}: difference between the original nominal radius and the minimum reprofiled radius less the wear before scrapping the axle;

ΔU_{sr} : maximum difference allowed by the maintenance rules between the mean wheel radius of the two bogies (bogie vehicle) or between the axle radius (non-bogie vehicle);

F_{lc}: value of the body sag according to A.3.4.1.2 at right angles to the point considered.

A.3.4.1.5 Vertical reduction formulae for passing over gradient transitions (including marshalling humps) and over braking, shunting or stopping devices

- vehicles having to pass over marshalling humps and activated rail brakes shall follow the reference profile in Figure A.5 (with $h_{\min} = 0,125$ m and 0,115 m) with its associated rules;
- vehicles having to pass over marshalling humps and non-activated rail brakes shall follow the reference profile in Figure A.6 (with $h_{\min} = 0,080$ m) and the same associated rules as in the previous case;
- vehicles not having to pass over marshalling humps shall follow the reference profile in Figure A.6 (with $h_{\min} = 0,080$ m) or the reference profile in A.5 (with $h_{\min} = 0,125$ m and 0,115 m), depending on kind of vehicles.

The formulae given in this subclause may also be applied for the calculation of bogie vehicles and related parts: in this case, the value a (vehicle wheelbase) in the formulae is to be replaced by p (bogie wheelbase).

A.3.4.1.5.1 Vehicles having to pass over marshalling humps

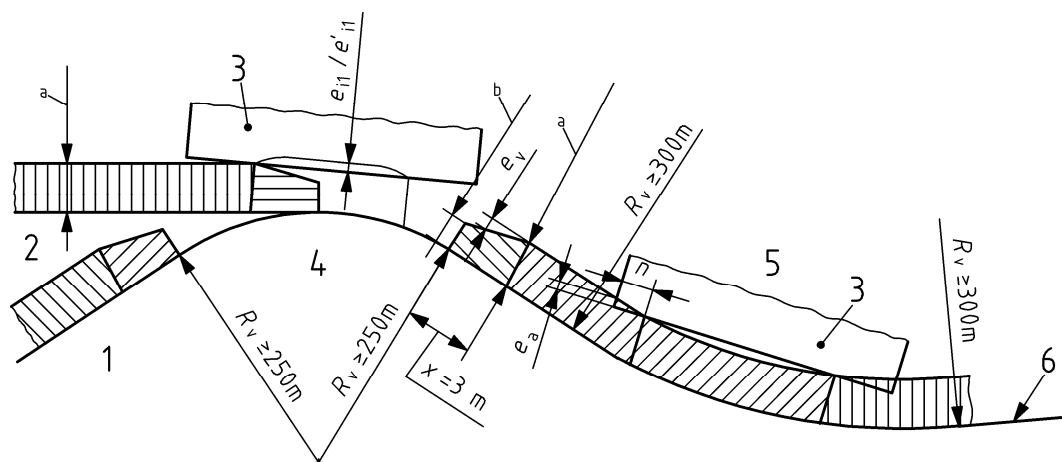
Normal values of the vertical increased reductions e_1 or e_a to be taken into account for empty coaches, empty or loaded vans and wagons

Vehicles, when they can be gravity-shunted, shall be capable of passing over activated rail brakes and other shunting or stopping devices located on non-vertically curved track and reaching to 0,115 m / 0,125 m above the running surface, up to 3 m from the end of convex transition curves of radius $R_V \geq 250$ m (dimension x).

They shall also be able to pass over such devices located inside or close to concave transition curves of radius $R_V \geq 300$ m

Vehicles, when they cannot be gravity-shunted, shall be capable of passing over non-activated rail brakes located as shown below relative to the convex and concave transition curves and their height is then reduced from 0,115 m / 0,125 m to 0,080 m above the running surface.

Under these conditions, the lower height of these vehicles, taking into account vertical displacements, shall be at least equal to 0,115 m /0,125 m or 0,08 m increased by the e_i or e_a quantities indicated in Figure A.8.



Key

- a 0,115 m or 0,125 m
- b 0,075 m or 0,085 m
- 1 classic hump
- 2 shunting gradient
- 3 vehicle
- 4 convex
- 5 concave
- 6 running surface

Figure A.8 — Reductions e_i or e_a in the convex and concave transitions

e_i or e_a : vertical increase of the lower part of the vehicle in relation to the height of 0,115 m /0,125 m or 0,080 m .

e_v : lowering of the rail brakes in relation to the 0,115 m /0,125 m or 0,080 m dimensions.

For sections between the end axles or bogie centres (values expressed in metres).

NOTE 1 The purpose of the numerical index applied to the e_i and e'_i values is to distinguish the normal values from the reduced values.

$$e_{i1} = \frac{n}{a} \cdot \frac{(a - n - 3)^2}{500 \cdot a} \text{ when } a \leq 17,80 \text{ m and } n < \left(\frac{a - 3}{3} \right) \quad (\text{A.6})$$

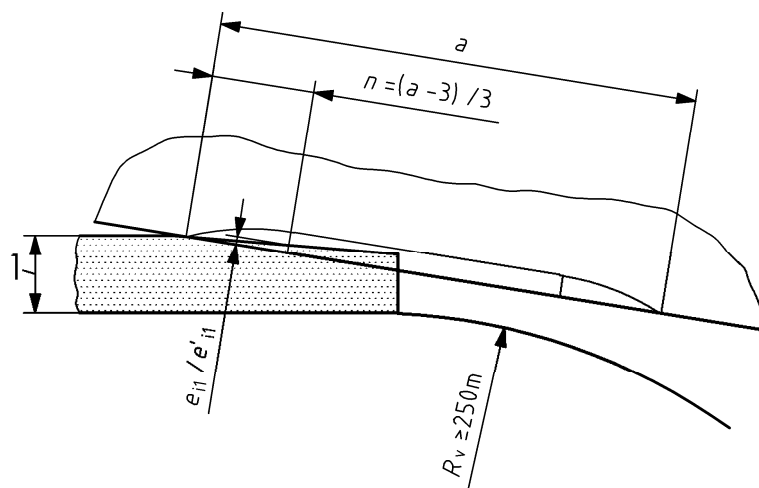
$$e_{i1} = \frac{(a-3)^3}{3375 \cdot a} \quad \text{when } a \leq 17,80 \text{ m and } n \geq \frac{(a-3)}{3} \quad 1 \quad (\text{A.7})$$

$$e'_{i1} = \left[\frac{27}{4} \frac{n}{a-3} \right] \left[1 - \frac{n}{a-3} \right]^2 \left[\frac{a^2}{3375} - 0,04 \right] \quad \text{when } a > 17,80 \text{ m and } n < \frac{a-3}{3} \quad (\text{A.8})$$

$$e'_{i1} = \frac{a^2}{3375} - 0,04 \quad \text{when } a > 17,80 \text{ m and } n \geq \frac{(a-3)}{3} \quad (\text{A.9})$$

When empty coaches and empty or loaded wagons and vans can be gravity-shunted, they shall also be able to pass over convex transition curves of radius ≥ 250 m, without any part other than the wheel flange dropping below the running surface (see Figure A.9).

This condition, which concerns the central part of the vehicles, comes in addition to those resulting from the e_i formulae for long vehicles.



For bogie vehicles, $a = p$

Key

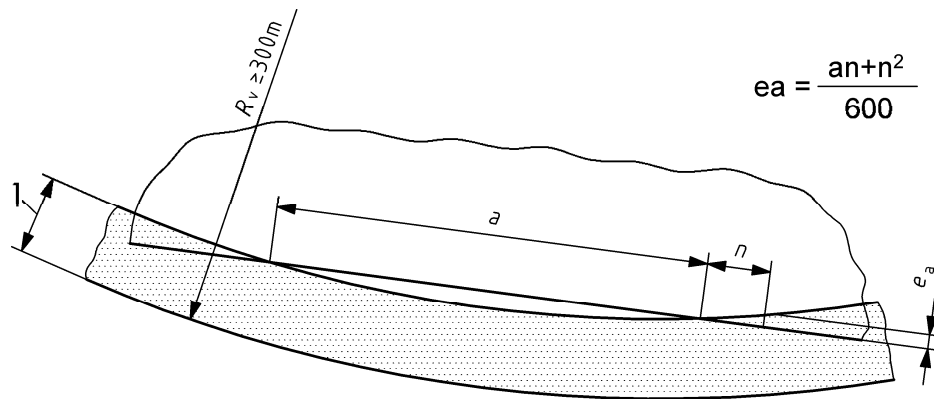
1 0,115 m/0,125 m or 0,080 m

Figure A.9 — Reductions e_{i1} or e'_{i1} for sections between centres or between the axles

¹ This formula for $n \geq \frac{(a-3)}{3}$ gives reductions greater than or equal to those resulting from the formula for $n < \frac{(a-3)}{3}$.

$$e_i = \left[\frac{an - n^2 + \frac{p^2}{4}}{500} - 0,125 \text{ or } 0,08 \right]_{>0} \quad (\text{A.10})$$

For sections located beyond the end axles or bogie centres (values expressed in metres), see Figure A.10.



Key

1 0,115 m/0,125 m or 0,080 m

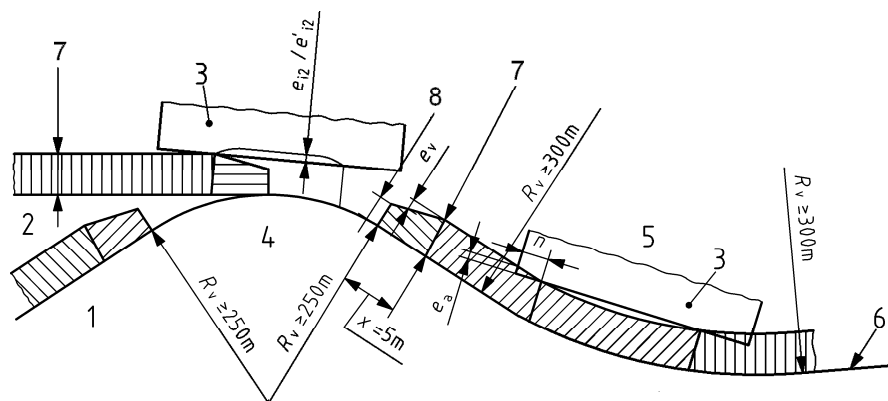
Figure A.10 — Increase e_a for sections outside bogie centres or end axles

Reduced values for the e_i increase (sections between the end axles or bogie centres) to be considered for certain vehicles for passing over gradient transitions including marshalling humps (see Figure A.11).

These reduced values are only tolerated for certain types of wagon, as they require a larger space than that determined using the normal values. These are, for example, pocket wagons used in rail/road combined traffic and identical or similar designs.

The use of these reduced values requires special precautions to be taken in certain marshalling yards with hump retarders at the base of a shunting gradient.

For these vehicles, the value of dimension x becomes 5 m.



Key

- 1 classic hump
- 2 shunting gradient
- 3 vehicle
- 4 convex
- 5 concave
- 6 running surface
- 7 0,115 m or 0,125 m
- 8 0,065 m or 0,075 m

Figure A.11 — Reductions in vertical transition curves

$$e_{i2} = \frac{n}{a} \cdot \frac{(a-n-5)^2}{500} \quad \text{when } a \leq 15,80 \text{ m and } n < \frac{(a-5)}{3} \quad (\text{A.11})$$

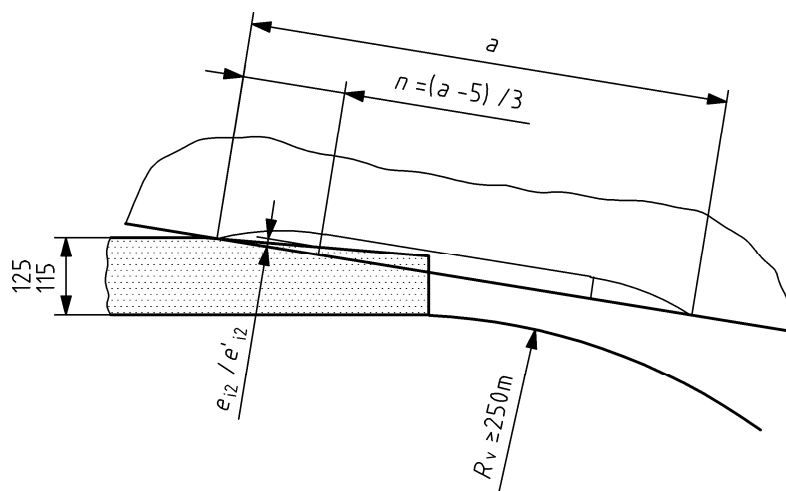
$$e_{i2} = \frac{(a-5)^3}{3375 \cdot a} \quad \text{when } a \leq 15,80 \text{ m and } n \geq \frac{(a-5)}{3} \quad (\text{A.12})$$

$$e'_{i2} = \left[\frac{27}{4} \frac{n}{a-5} \right] \left[1 - \frac{n}{a-5} \right]^2 \left[\frac{a^2}{3375} - 0,05 \right] \quad \text{when } a > 15,80 \text{ m and } n < \frac{(a-5)}{3} \quad (\text{A.13})$$

$$e'_{i2} = \frac{a^2}{3375} - 0,05 \quad \text{when } a > 15,80 \text{ m and } n \geq \frac{(a-5)}{3} \quad (\text{A.14})$$

² This formula for $n \geq \frac{a-5}{3}$ gives reductions greater than or equal to those resulting from the formula for $n < \frac{a-5}{3}$

When they can be gravity-shunted, the wagons shall also be able to pass over convex transition curves with a radius greater than or equal to 250 m, without any part other than the wheel flange dropping below the running surface. This condition, which concerns the central part of the wagons, comes in addition to those resulting from the e_i formulae for long wagons (see Figure A.12).



For bogie vehicles $a = p$.

Key

1 0,115 m or 0,125 m or 0,080 m

Figure A.12 — Reductions e_{i2} or e'_{i2} for sections between bogie centres or between the axles (long wagons)

$$e_i = \left[\frac{an - n^2 + \frac{p^2}{4}}{500} - 0,125 \right]_{>0} \quad (\text{A.15})$$

Table A.2 — Values of e_i and e'_i (expressed in mm) as functions of a and n (expressed in m)

$a \backslash n$	> 6	5,5	5	4,5	4	3,5	3	2,5	2	1,5	1	0,5	0
20	79 69	78 69	78 69	76 68	73 66	69 63	63 59	57 54	49 46	39 37	28 27	15 14	0 0
19,5	73 63	73 63	72 63	71 62	68 61	65 59	60 55	54 50	46 43	37 35	26 25	14 14	0 0
19	67 57	67 57	67 57	66 57	64 56	60 54	56 51	50 46	43 40	35 33	25 24	13 13	0 0
18,5	61 51	61 51	61 51	61 51	59 51	56 49	52 47	47 43	41 37	33 30	23 22	13 12	0 0
18	56 46	56 46	56 46	56 46	54 46	52 45	48 42	44 39	38 34	31 28	22 20	12 11	0 0
17,5	52 41	52 41	52 41	51 41	50 41	48 40	45 38	41 35	36 31	29 26	21 19	11 10	0 0
17	48 36	48 36	48 36	48 36	47 36	45 35	43 34	39 31	34 28	28 23	20 17	11 9	0 0
16,5	44 31	44 31	44 31	44 31	44 31	42 30	40 30	37 28	32 25	26 20	19 15	10 8	0 0
16	41 26	41 26	41 26	41 26	41 26	40 26	38 25	34 24	30 21	25 18	18 13	10 7	0 0
15,5	37 22	37 22	37 22	37 22	37 22	37 22	35 22	32 21	28 19	23 16	17 12	9 6	0 0
15	34 20	34 20	34 20	34 20	34 20	34 20	32 20	30 19	27 17	22 14	16 11	9 6	0 0
14,5	31 18	31 18	31 18	31 18	31 18	31 18	30 17	28 17	25 16	21 13	15 10	8 6	0 0
14	28 15	28 15	28 15	28 15	28 15	28 15	27 15	26 15	23 14	19 12	14 9	8 5	0 0

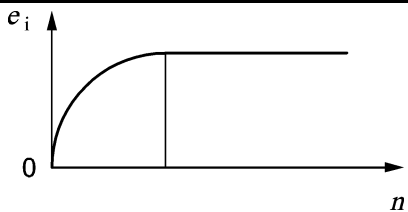
EN 15273-2:2009 (E)

Table A.2 (continued)

a \ n	> 6	5,5	5	4,5	4	3,5	3	2,5	2	1,5	1	0,5	0
13,5	25 13	25 13	25 13	25 13	25 13	25 13	25 13	24 13	21 13	18 11	13 8	7 5	0 0
13	23 12	23 12	23 12	23 12	23 12	23 12	23 12	22 12	20 11	17 10	12 8	7 4	0 0
12,5	20 10	20 10	20 10	20 10	20 10	20 10	20 10	20 10	18 10	15 9	12 7	7 4	0 0
12	18 8	18 8	18 8	18 8	18 8	18 8	18 8	18 8	16 8	14 8	11 6	6 4	0 0
11,5		16 7	16 7	16 7	16 7	16 7	16 7	16 7	15 7	13 7	10 5	6 3	0 0
11		14 6	14 6	14 6	14 6	14 6	14 6	14 6	13 6	12 6	9 5	5 3	0 0
10,5			12 5	12 5	12 5	12 5	12 5	12 5	12 5	10 5	8 4	5 2	0 0
10			10 4	10 4	10 4	10 4	10 4	10 4	10 4	9 4	7 3	4 2	0 0
9,5				9 3	9 3	9 3	9 3	9 3	9 3	8 3	6 3	4 2	0 0
9				7 2	7 2	7 2	7 2	7 2	7 2	7 2	6 2	3 1	0 0
8,5					6 1	6 1	6 1	6 1	6 1	6 1	5 1	3 1	0 0
8					5 1	5 1	5 1	5 1	5 1	5 1	4 1	3 1	0 0
7,5						4 1	4 1	4 1	4 1	4 1	3 1	2 1	0 0

Table A.2 (continued)

$\begin{matrix} n \\ a \end{matrix}$	> 6	5,5	5	4,5	4	3,5	3	2,5	2	1,5	1	0,5	0
7						$\begin{matrix} 3 \\ 0 \end{matrix}$	$\begin{matrix} 3 \\ 0 \end{matrix}$	$\begin{matrix} 3 \\ 0 \end{matrix}$	$\begin{matrix} 3 \\ 0 \end{matrix}$	$\begin{matrix} 3 \\ 0 \end{matrix}$	$\begin{matrix} 3 \\ 0 \end{matrix}$	$\begin{matrix} 2 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$
6,5							$\begin{matrix} 2 \\ 0 \end{matrix}$	$\begin{matrix} 2 \\ 0 \end{matrix}$	$\begin{matrix} 2 \\ 0 \end{matrix}$	$\begin{matrix} 2 \\ 0 \end{matrix}$	$\begin{matrix} 2 \\ 0 \end{matrix}$	$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$
6										$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$
5,5										$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 1 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$
5										$\begin{matrix} 0 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$
4,5										$\begin{matrix} 0 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$	$\begin{matrix} 0 \\ 0 \end{matrix}$



(a-3)/3 or (a-5)/3



1 normal values

2 reduced values

A.3.4.1.5.2 Vehicles that shall not pass over marshalling humps

When empty coaches, wagons suitable for international traffic and empty or loaded vans are not allowed to pass over marshalling humps on account of their length, they shall however comply with the GIC1 profile when placed on a non-vertically curved track, so as to allow for the use of shunting or stopping devices. All other vehicles shall use the GIC2 profile

A.3.4.1.6 All vehicles

All vehicles shall be able to pass over convex or concave transition curves of radius $R_v \geq 500$ m, without any part other than the wheel flange dropping below the running surface.

In the zones on the outside of the wheels, the height of the rolling stock relative to the running surface shall increase by the value:

$$\left(dg_{iv} \text{ or } dg_{av} - \frac{50000}{R_v} \right)_{>0} \text{ where } R_v \geq 500 \text{ m.}$$

For sections located between the end axles or bogie centres (normal values expressed in metres):

$$\left[\frac{an - n^2 + \frac{p^2}{4}}{1000} - 0,08 \right]_{>0} \quad (\text{A.16})$$

For sections located beyond the end axles or the bogie centres (normal values expressed in metres):

$$\left[\frac{an + n^2 - \frac{p^2}{4}}{1000} - 0,08 \right]_{>0} \quad (\text{A.17})$$

A.3.4.1.7 Special conditions

The following special cases shall be taken into account:

- 1) transition curve for vehicles fitted with automatic couplers;
- 2) angle of inclination for vehicles used on ferries – see A.3.7.

A.3.4.2 Determination of maximum heights above the running surface

The maximum heights above the running surface of an empty vehicle with no wear and its components located close to the upper part of the gauge $h \geq 3,25$ m are determined taking into account the vertical displacements described in the following subclauses.

A.3.4.2.1 Bending effect of structures

— body: longitudinal sag neglected, except for wagons.

A.3.4.2.2 Suspension extension

The extension of the suspensions is taken into account by considering a 10 mm displacement for each level of suspension.

The vertical component of quasi-static displacements is not taken into account.

A.3.4.2.3 Gradient transitions

The height of the vehicles relative to the running surface shall be reduced:

- for the sections located between the end axles or the bogie centres (normal values expressed in metres) by:

$$\left[\frac{an - n^2 + \frac{p^2}{4}}{1000} - 0,08 \right]_{>0} \quad (\text{A.18})$$

- for the sections located beyond the end axles or the bogie centres (normal values expressed in metres)

$$\left[\frac{an + n^2 - \frac{p^2}{4}}{1000} - 0,08 \right]_{>0} \quad (\text{A.19})$$

A.3.5 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 $h_{\min} = 0,100$ m.

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

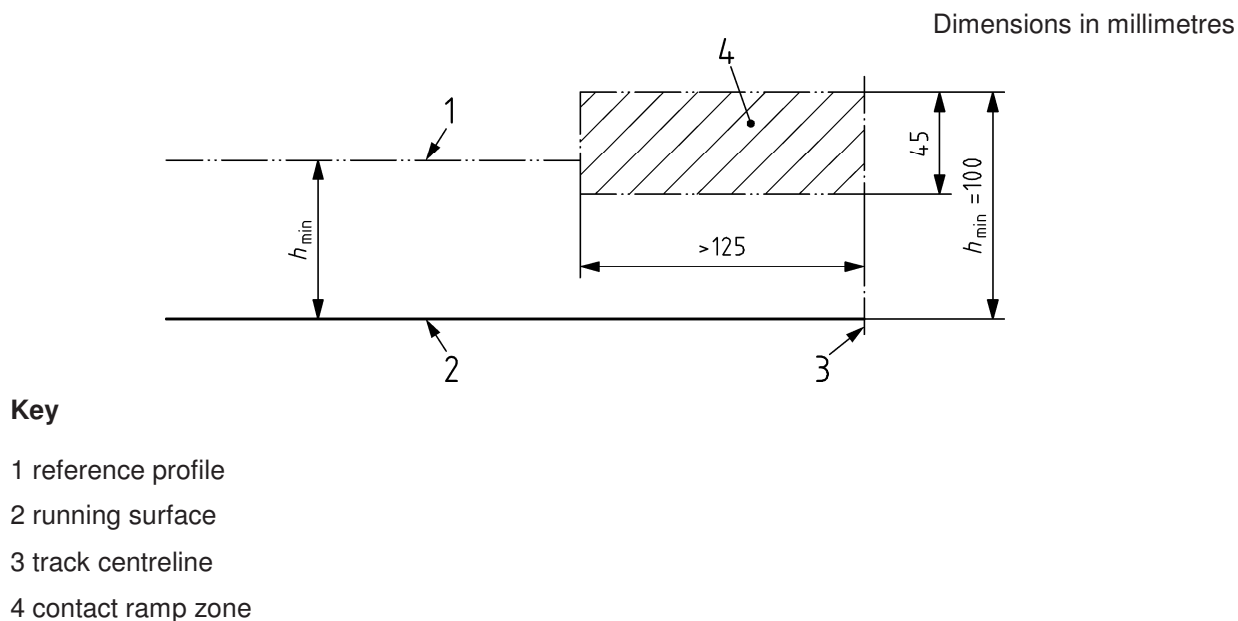
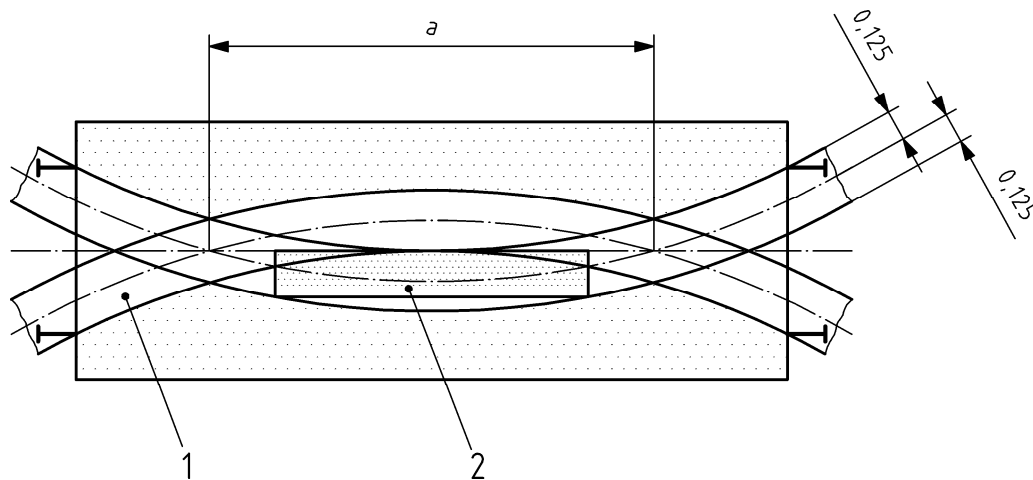


Figure A.13 — Contact ramp zone

The contact brush may descend 45 mm into the zone intended for installation of the contact ramps.

Vehicle parts likely to descend less than $h_{\min} = 0,10$ m from the running surface shall not be located less than 0,125 m from the track centreline when the vehicle is installed on a curved track of radius $R = 250$ m and track width $l_{\max}$.

The free space of 0,125 m on either side of the centreline is provided for a contact brush width of 0,128 m.



Key

- 1 zone for vehicle not capable of descending less than 100 mm from running surface
- 2 contact ramp

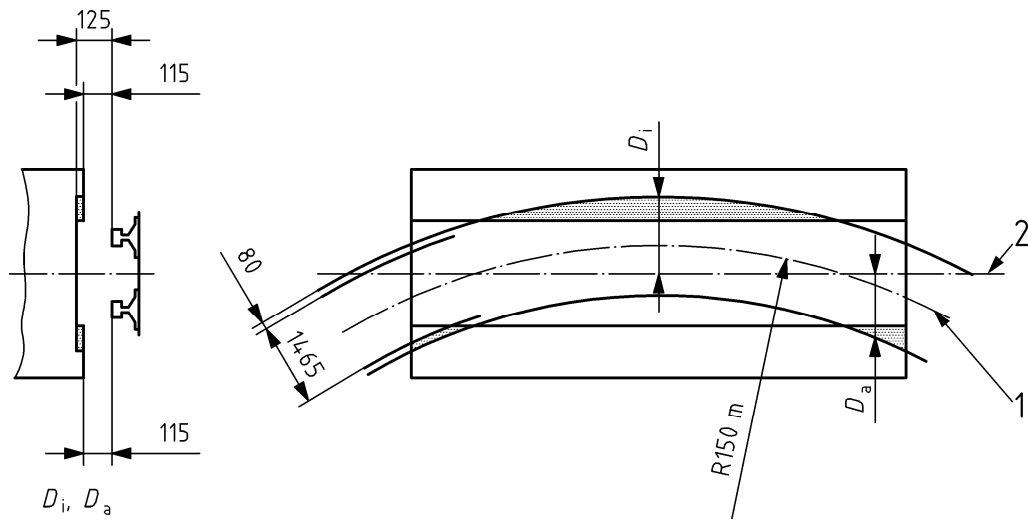
Figure A.14 — Space for contact ramps below the vehicles

The width of the contact ramp zone for parts inside the bogies is fixed as 300 mm.

A.3.6 Use of shunting devices on curved tracks

Rail brakes and other shunting and stopping devices which, when activated, can reach the height of 0,115 m or 0,125 m, in particular retarders, 0,125 m high, may be installed on curves of radius $R \geq 150$ m (see Figure A.15).

Unless otherwise indicated, dimensions in millimetres



Key

- 1 track centreline
- 2 vehicle centreline

Figure A.15 — Distances D_i and D_a

It follows that the application limit for the 0,115 m or 0,125 m dimensions at a constant distance from the inner edge of the rail (0,080 m) is a variable distance D from the centreline of the vehicle, as shown in the figure above

The formulae are³

$$D_i = 0,080 + 1,465 - \frac{1,410}{2} + \frac{a \cdot n_i - n_i^2 + \frac{p^2}{4}}{300} = 0,840 + \frac{a \cdot n_i - n_i^2 + \frac{p^2}{4}}{300} \quad (\text{A.20})$$

$$D_a = 0,080 + 1,465 - \frac{1,410}{2} + \frac{a \cdot n_a + n_a^2 - \frac{p^2}{4}}{300} = 0,840 + \frac{a \cdot n_a + n_a^2 - \frac{p^2}{4}}{300} \quad (\text{A.21})$$

A.3.7 Conditions for embarkation onto ferries

To verify the embarking capability, the allowable minimum height $h_{\min}$ for the vehicle is determined.

The formula takes into account:

- the fixed allowance M_{fb} :

$$M_{fb} = 0,06 \text{ for coaches}$$

³ In the particular case involving the use of shunting devices, the influence of clearances $q + w$ can be considered as negligible.

$M_{fb} = 0,02$ for wagons

- angle made by the link span α'' . The geometric overthrow resulting from angle α'' shall be taken into account.
- wear of body parts (part of Δh_1);
- for steel springs or rubber springs (part of Δh_1 and Δh_2):
 - deflection under maximum static load;
 - deflection resulting from tolerances on flexibility (maintenance limit values);
 - deflection due to creep;
- for air springs, (part of Δh_2):
 - total deflection resulting from deflated air springs (including back-up suspension, if any);
 - equipment to compensate for the change in wheel radius and suspension creep and wear may be taken into account.

Convex vertical deviation in the zone between the bogie centres (or axles).

All the axles shall be considered with the minimum wheel radius Δr_w .

The vertical sag f due to the load shall be taken into account.

The lower parts of vehicle shall remain above:

$$h_{\min} = \Delta r_w + \Delta h_1 + \Delta h_2 + f + \frac{n \cdot (a - n)}{a} \cdot \tan \alpha'' + M_{fb} \quad (\text{A.22})$$

Concave vertical deviation in the zone beyond the centres (or axles).

All the axles shall be considered with the minimum wheel radius – wear Δr_w . For one bogie, the minimum wheel (or axle) radius – wear Δr_w , shall be taken into account and, for the other bogie, the maximum allowed difference between the bogies (or axles) - wear Δr_{wb} .

At one of the ends, the combined displacement due to the springs shall be taken into account with the minimum wheel radius and the normally inflated air springs at the other end.

Therefore, the lower parts of the vehicle shall remain above:

$$h_{\min} = \Delta r_w + \Delta h_1 + \Delta h_2 + f + \frac{n \cdot (a - n)}{a} \cdot \tan \alpha'' + M_{fb} \quad (\text{A.23})$$

Table A.3 — List of ferry routes

ROUTE	Angle made by the link span α''
Helsingör – Helsingborg	3°30'
Korsør – Nyborg	
	2°30'
	3°30'
Rødby Færge - Puttgarden	
Sassnitz Hafen - Trelleborg	2°30'
Villa S.G. – Messina	1°30'
Reggio C. – Messina	1°30'

A.3.8 Taking account of the transverse displacements of vehicles

These displacements are the sum of the following displacements:

- 1) geometric displacements resulting from the vehicle running through curves and straight track (additional overthrows, transverse clearances, etc.), where the vehicle centreline is considered to be perpendicular to the running surface;
- 2) quasi-static displacements resulting from the inclination of the suspended parts under the influence of gravity (canted track) and/or centrifugal acceleration (curved track);
- 3) transverse bending of the vehicle body is generally disregarded except for those special types of wagon or heavily-loaded wagons for which these values are particularly high.

A.3.8.1 Quasi-static displacements (term concerning vehicle roll on its suspension and its dissymmetry when this is greater than 1°)

The term z_{kin} is the deviation from the track central position and is the sum of two parts:

$$\frac{s}{30}(h - h_c)_{>0}$$

Term concerning the roll due to the suspension (transverse displacement due to the flexibility of the suspension, under the influence of cant excess or deficiency of 0,05m);

$$\tan(\eta_0 - I^\circ)_{>0} \cdot |h - h_c|$$

Term concerning the dissymmetry (transverse displacement due to the part of the dissymmetry exceeding 1°).

If necessary, this sum shall be increased by a term including the cant excess or deficiency of 0,2 m when the s and h_c values exceed that taken into account by the infrastructure

$$\left[\frac{s}{10} (h - h_c)_{>0} - 0,04 \cdot (h - 0,5)_{>0} \right]_{>0}$$

For sprung parts of height h , the above terms give the formula:

$$z_{\text{kin}} = \frac{s}{30} (h - h_c)_{>0} + [\tan(\eta_0 - 1^\circ)_{>0}] \cdot |h - h_c| + \left[\frac{s}{10} (h - h_c)_{>0} - 0,04 \cdot (h - 0,5)_{>0} \right]_{>0} \quad (\text{A.24})$$

A.3.8.1.1 Special cases

$$\text{— if } \left\{ \begin{array}{l} h > h_c \text{ and } 0,5 \text{ m} \\ s \leq 0,4 \\ \eta_0 \leq 1^\circ \end{array} \right\} z_{\text{kin}} = \frac{s}{30} (h - h_c)$$

$$\text{— if } \left\{ \begin{array}{l} h < 0,5 \text{ m} \\ \eta_0 \leq 1^\circ \\ \text{and for any value of } h_c \text{ and } s \end{array} \right\} z_{\text{kin}} = 0$$

$$\text{— if } h = h_c \quad z_{\text{kin}} = 0$$

$$\text{— for unsprung parts } z_{\text{kin}} = 0.$$

A.3.8.1.2 Effect of side bearer clearances for bogie wagons

- for wagons whose side bearer clearance is less than or equal to 5 mm, this effect is included in the dissymmetry angle of 1° , and conventionally is written $\eta_0 = 1^\circ$

Term " z_{kin} " taking into account a side bearer clearance less than or equal to 5 mm becomes:

$$z_{\text{kin}} = \frac{s}{30} (h - h_c)_{>0} + \left[\frac{s}{10} (h - h_c)_{>0} - 0,04 \cdot (h - 0,5)_{>0} \right]_{>0} \quad (\text{A.25})$$

and the special cases in the previous subclause shall be taken into account.

- for wagons fitted with bogies whose side bearer clearance is greater than 5 mm, account shall be taken of the additional inclination α of the vehicle body, expressed as follows:

$$\alpha = \arctan \frac{J - 0,005}{b_G}$$

This additional roll α leads to displacement of the suspension which, when multiplied by the flexibility coefficient s , gives a rotation of the body αs (where s is the flexibility coefficient)

The total additional roll may be expressed as:

$$\alpha(1+s)$$

The term z_{kin} taking into account a side bearer clearance greater than 5 mm becomes:

$$z_{\text{kin}} = \frac{s}{30}(h-h_c)_{>0} + \left\{ \tan \left[\eta'_0 + \left(\arctan \frac{(J-0,005)_{>0}}{b_G} \right) (1+s) - 1^\circ \right] \right\}_{>0} \cdot |h-h_c| + \left[\frac{s}{10}(h-h_c)_{>0} - 0,04(h-0,5)_{>0} \right]_{>0} \quad (\text{A.26})$$

where

η'_0 is the dissymmetry corresponding to a side bearer clearance of 5 mm.

A.3.9 Formulae

A.3.9.1 Reduction formulae applicable to traction units

A.3.9.1.1 Traction units having clearance w independent of the installation radius or linearly variable as a function of the curve

A.3.9.1.1.1 For sections between the bogie centres or between the end axles of vehicles not fitted with bogies

$$\text{When } a \cdot n_i - n_i^2 + \frac{p^2}{4} - 500(w_\infty - w_i(250)) \leq \begin{matrix} 4 \\ 7,5 \end{matrix} \quad 5$$

$$E_i = \frac{1,465-d}{2} + q + w_\infty + z_{\text{kin}} - 0,015 \quad (\text{A.27})$$

$$\text{When } a \cdot n_i - n_i^2 + \frac{p^2}{4} - 500(w_\infty - w_i(250)) > \begin{matrix} 4 \\ 7,5 \end{matrix} \quad 5$$

$$E_i = \frac{a \cdot n_i - n_i^2 + \frac{p^2}{4}}{500} + \frac{1,465-d}{2} + q + w_{i(250)} + z_{\text{kin}} + [x_i]_{>0} - \begin{matrix} 4 \\ 0,025 \\ 5 \\ 0,030 \end{matrix} \quad (\text{A.28})$$

$$\text{with } x_i = \frac{1}{750} \left(a \cdot n_i - n_i^2 + \frac{p^2}{4} - 100 \right) + w_i(150) - w_i(250) \quad (\text{A.29})$$

⁴ This value applies to those parts not higher than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical displacement.

⁵ This value applies to parts higher than 0,400 m above the running surface, with the exception of those covered by footnote 4) above.

A.3.9.1.1.2 For sections beyond the bogie centres or end axles of vehicles not fitted with bogies

$$\text{When } a \cdot n_a + n_a^2 - \frac{p^2}{4} - 500 \left[\left(w_{\infty} - w_i(250) \right) \frac{n_a}{a} + \left(w_{\infty} - w_a(250) \right) \frac{n_a + a}{a} \right] \leq \begin{vmatrix} 5 \\ 7,5 \end{vmatrix} \quad \begin{matrix} 4 \\ 5 \end{matrix}$$

$$E_a = \left(\frac{1,465 - d}{2} + q + w_{\infty} \right) \frac{2n_a + a}{a} + z_{kin} - 0,015 \quad (\text{A.30})$$

$$\text{When } a \cdot n_a + n_a^2 - \frac{p^2}{4} - 500 \left[\left(w_{\infty} - w_i(250) \right) \frac{n_a}{a} + \left(w_{\infty} - w_a(250) \right) \frac{n_a + a}{a} \right] > \begin{vmatrix} 5 \\ 7,5 \end{vmatrix} \quad \begin{matrix} 4 \\ 5 \end{matrix}$$

$$E_a = \frac{a \cdot n_a + n_a^2 - \frac{p^2}{4}}{500} + \left(\frac{1,465 - d}{2} + q \right) \frac{2n_a + a}{a} + w_i(250) \frac{n_a}{a} + w_a(250) \frac{n_a + a}{a} + z_{kin} + [x_a]_{>0} - \begin{vmatrix} 0,025 \\ 0,030 \end{vmatrix} \quad (\text{A.31})$$

$$\text{with: } x_a = \frac{1}{750} \left(a \cdot n_a + n_a^2 - \frac{p^2}{4} - 120 \right) + \left(w_i(150) - w_i(250) \right) \frac{n_a}{a} + \left(w_a(150) - w_a(250) \right) \frac{n_a + a}{a} \quad (\text{A.32})$$

A.3.9.1.2 Traction units having a clearance w varying non-linearly as a function of the curve (exceptional case)

- in addition to the curves of radius $R = 150$ m and 250 m for which Formulae (A 33), (A 34) and (A 35), (A 36) are identical to Formulae (A 27), (A 28) and (A 30), (A31) respectively, Formulae (A 33), (A 34), (A 35) and (A 36) shall be applied for the value of R for which the change in w as a function of $\frac{1}{R}$ shows a discontinuity, i.e. the value for R from which the variable stops begin to work;
- for each section of the traction unit, the reduction to be used is the greatest of those obtained from the application of the formulae, in which the value of R to be used is the one which gives the highest value for the part between square brackets.

A.3.9.1.2.1 Sections between the bogie centres or between the end axles of vehicles not fitted with bogies

When $\infty > R \geq 250$ m.

$$E_i = \left[\frac{a \cdot n_i - n_i^2 + \frac{p^2}{4} - \begin{vmatrix} 5^{(1)} \\ 7,5^{(2)} \end{vmatrix}}{2R} + w_{i(R)} \right] + \frac{1,465 - d}{2} + q + z_{kin} - 0,015 \quad (\text{A.33})$$

when $250 \text{ m} > R \geq 150 \text{ m}$

.