# APTU Uniform Rules (Appendix F to COTIF 1999)

# Uniform Technical Prescriptions (UTP) relating to the Subsystem Rolling Stock

# FREIGHT WAGONS - ANNEX C

## VEHICLE TRACK INTERACTION AND GAUGING

# KINEMATIC GAUGE

*Explanatory note:*

*The texts of this UTP which appear across two columns are identical to corresponding texts of the European Union regulations. Texts which appear in two columns differ; the left-hand column contains the UTP regulations, the right-hand column shows the text in the corresponding EU regulations. The text in the right-hand column is for information only and is not part of the OTIF regulations.*

*OTIF UTP* | *Corresponding text in EU regulations* [1] | *EU ref.* [2]

## C.1 SCOPE OF APPLICATION

The loading gauges available in different countries are classified as follows:

- Gauge allowed with no restriction: G1
  The target gauge, available on all lines (except the UK, see Annex T)
- Gauge whose free use is limited to certain, precisely specified routes: Gauges GA, GB, GC
- Gauges the use of which must be covered by a prior agreement between the Infrastructure Managers concerned:
  Gauges G2, 3.3, GB-M6, GB1, GB2, etc.
- Loads carried on wagons
  For the loads carried on wagons, only the load profiles and the loading methods set down in Appendix 6 shall be accepted.
- Combined transport
  For the requirements of combined transport traffic, using load units of well-defined volume (swap bodies, containers and semi-trailers) on specified wagons (Ref. PTU chapter 3.2.1).
- Interoperable high-speed vehicles.
  The vehicles of high-speed trainsets that are interoperable within the European Community shall be built to the loading gauges prescribed in Section 4.1.4 of the Rolling Stock TSI.
- Rolling stock equipped with cant deficiency compensation systems
  Such rolling stock shall be checked by the method set down in Appendix 3.
- Pantographs
  The space envelope of the pantographs and roof-mounted equipment shall be checked according to Chapter 4.2.2.5.
- OSSJD loading gauges
  OSSJD member states use particular loading gauges. As soon as the technical and

[1] TSI Freight Wagons – The Annex to the Commission Decision 2006/861/EC published in the EU Official Journal L344 on 08.12.2006 as amended by Commission Decision 2009/107/EC published in EU Official Journal L45 on 14.02.2009.

[2] If no EU reference is indicated, it means that the chapter/section number is the same as in the OTIF text.

application documents become available, the corresponding text shall be the subject of Appendix 7

- Doors and steps
  The rules pertaining to doors and steps are set down in Appendix 1.
- Compression of suspensions for the zones located outside the support polygon B — C — D
  The rules are given in Appendix 2.
- Utilisation of the existing margins available on the infrastructure by vehicles with defined parameters
  Such rolling stock shall be checked by the method given in Appendix 4.

# C.2 GENERAL PART

## C.2.1 LIST OF NOTATIONS USED

A : angular displacement coefficient of bogie
a : distance between the end axles of vehicles not fitted with bogies or between the pivots of bogie vehicles (see Note)
b : half width of the vehicle (see diagram in Appendix 2)
b1 : half distance between the primary suspension springs (see diagram in Appendix 2)
b2 : half distance between the secondary suspension springs (see diagram in Appendix 2)
bG : half distance between the side-bearers
bw : half width of the pantograph bow
C : roll centre (see Figure 3)
d : the outer distance between the wheel flanges measured at a point 10 millimetres below the running treads, with the flanges worn to the permissible limit, the absolute limit being 1,410 m. This limit may vary according to the maintenance criteria for the vehicle under consideration
dga : outer curve overthrow
dgi : inner curve overthrow
D : lateral movement
Ea : external reduction
Ei : internal reduction
E'a : external deviation in relation to the movement authorised at the pantograph upper verification point (6,5 m)
E'i : internal deviation in relation to the movement authorised at the pantograph upper verification point (6,5 m)
E"a : external deviation in relation to the movement authorised at the pantograph lower verification point (5,0 m)
E"i : internal deviation in relation to the movement authorised at the pantograph lower verification point (5,0 m)
ea : external vertical reduction at the lower part of vehicles
ei : internal vertical reduction at the lower part of vehicles
f : vertical sag (see Appendix 2)
h : height in relation to the running surface
hc : height of the roll centre of the transverse cross-section of the vehicle in relation to the running surface
ht : installation height of the pantograph lower articulation in relation to the running surface
J : side-bearers play
J'a, J'i : difference between the movements resulting from the calculation and movements due to play effects
l : track gauge
n : distance between the section considered and the adjacent end axle or nearest pivot (see Note)

na : n for the sections located outside the axles or bogie pivots
ni : n for the sections located between the axles or bogie pivots
nμ : distance of the section considered to the motor bogie pivot of multiple units (see Note)
p : bogie wheel base
p' : trailer bogie wheel base for multiple units
q : lateral play between axle and bogie frame or between axle and vehicle body in the case of axle vehicles
R : level curve radius
Rv : vertical curve radius
s : vehicle flexibility coefficient
S : projection
So : maximum projection
t : pantograph flexibility index: lateral movements expressed in metres to which the bow is subjected when raised to 6,50 m under the effect of a 300 N lateral force
w : lateral play between bogie and vehicle body
w∞ : lateral play between the bogie and the vehicle body on straight track
wa : lateral play between the bogie and vehicle body on the outside of the curve
wi : lateral play between the bogie and vehicle body on the inside of the curve
wa(R) : lateral play between the bogie and vehicle body on the outside of an R radius curve
wi(R) : lateral play between the bogie and vehicle body on the inside of an R radius curve

w'∞ — w'a — w'i — w'a(R) — w'i(R) are the same for the trailer bogies of multiple units.

xa : additional reduction for extra-long vehicles outside the bogie pivots
xi : additional reduction for extra-long vehicles between the bogie pivots
y : distance from the effective pivot to the geometric centre of the bogie (see Note)
z : deviation in relation to the median position due to quasi-static inclination and to dissymetry
z' : difference between the lateral inclination based on calculation and the actual inclination of the pantograph upper verification point
z" : difference between the lateral inclination based on calculation and the actual inclination of the pantograph lower verification point
α : additional vehicle body inclination due to side-bearers play
δ : inclination of canted track (see figure 3)
ηo : angle of vehicle asymmetry due to construction tolerances, to suspension adjustment and to uneven load distributions (in degrees)
ϑ suspension adjustment tolerance: inclination which the vehicle body may attain as a result of suspension adjustment imperfections when the vehicle is resting empty on level track (in radians)
μ : rail-wheel adhesion coefficient
τ : pantograph construction and installation tolerance: deviation tolerated between the vehicle body centre line and the middle of the bow presumed to be raised to 6,5 m without any lateral stress

**Note:**

In the case of vehicles without fixed bogie pivots, in order to determine the a and n values, the meeting point of the bogie longitudinal centre line with that of the vehicle body will be considered as a fictional pivot, determined graphically, when the vehicle is on a 150 m radius curve, the play effects being evenly distributed and the axles centred on the track: if y is the distance of the fictional pivot from the geometric centre of the bogie (at equal distance from the end axles), $p^2$ will be replaced by

$(p2 - y2)$ and $p'^2$ by $(p'2 - y2)$

in the formulae.

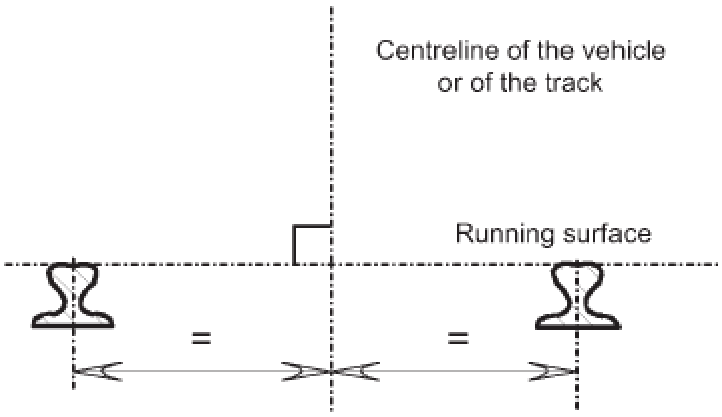
## C.2.2 DEFINITIONS

### C.2.2.1 Normal co-ordinates

The expression ‘normal co-ordinates’ is used for orthogonal axes defined in a plane normal to the centreline of the track in nominal position; one of these axes, sometimes called horizontal, is the intersection of the specified plane and the running surface; the other is the perpendicular to this intersection at equal distance from the rails.

For calculation purposes, this centreline and the vehicle centreline must be considered as coincident in order to be able to compare the vehicle construction gauges and the lineside structure limit gauges, both calculated on the basis of the kinematic gauge reference profile which is common to both.

*Fig. C1*




### C2.2.2 Reference profile

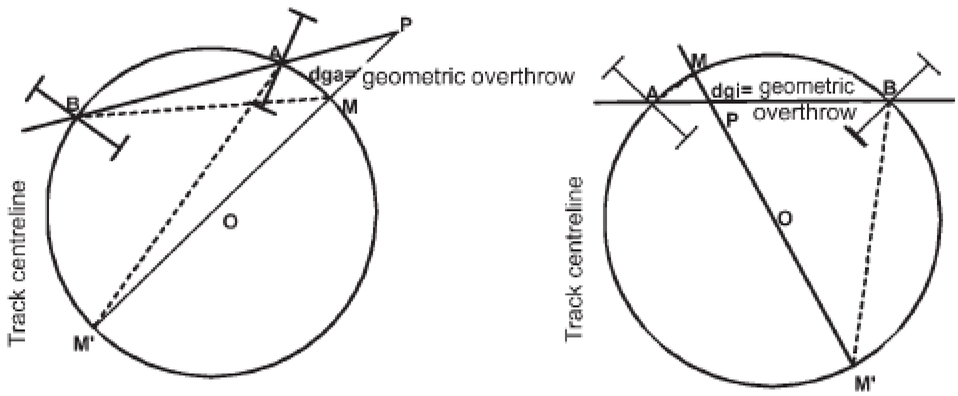
Profile related to the normal co-ordinates, always accompanied by associated rules used, for rolling stock, to define the vehicle maximum construction gauge.

### C.2.2.3 Geometric overthrow

The expression geometric overthrow means, for an element of a vehicle located on a radius R curve, the difference between the distance from this element to the track centreline and that which would exist on straight track, the axles being, in both cases, placed in a median position on the track, the play also being evenly distributed, the vehicle symmetrical and not tilted on its suspensions; in other words, it is that part of the vehicle element offset which is due to the track curvature.

On the same side of the track centreline, all the points in the same vehicle body cross-section have the same geometric overthrow.

Fig.C2




### C.2.2.4 Roll centre C

When the vehicle body is subjected to a lateral force parallel to the running surface (gravity component, see figure 3a, or centrifugal force, see figure 3b) it tilts on its suspensions.

If the vehicle lateral play and the effect on its dampers have reached their limits in this condition, the XX' centreline of a lateral section takes up a X1X'1 position.

In routine cases of vehicle lateral movements, the position of point C is independent of the lateral force involved. Point C is known as the roll centre of the vehicle and its distance $h_c$ from the running surface is known as the height of the roll centre.

The value $h_c$ can be measured or calculated. In the case of extreme vehicle/bogie positions for calculating the maximum construction gauge, this height $h_c$ must be taken at one of the vehicle body/bogie bump stops concerned (centre or rotational stops); in the case where it can be neither measured nor calculated, $h_c$ should be taken as equal to 0,5 m.

Fig.C3

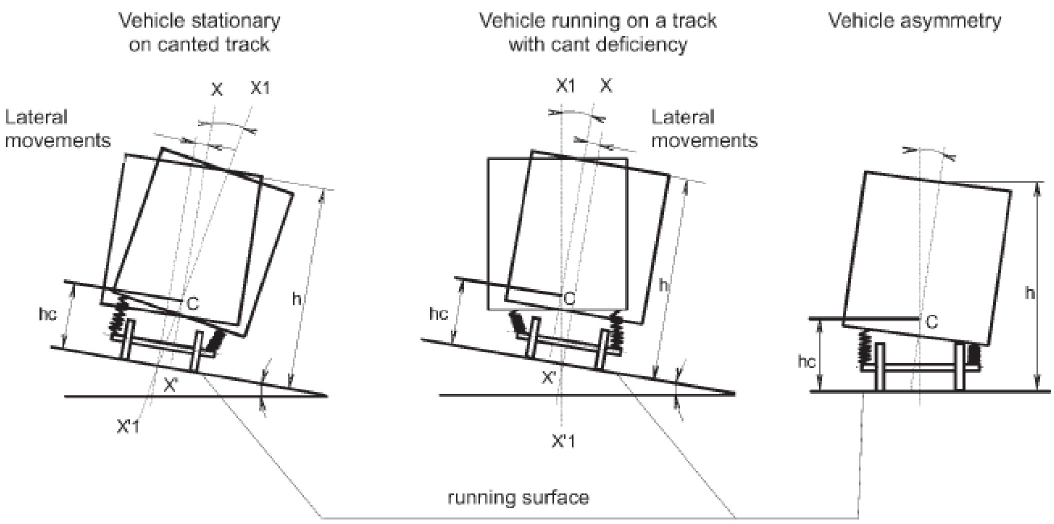



Fig C3a Fig C3b Fig C3c

### C.2.2.5 Asymmetry

The asymmetry of a vehicle is defined as the angle ηo that would be formed between the vertical and the centreline of the body of a stationary vehicle on level track in the absence of friction (see Figure 3c).

Asymmetry may result from constructional defects, unevenly adjusted suspension (scotching, side-bearers, pneumatic levelling valves, etc.) and from an off-centre load.

**2.2.6 Coefficient of flexibility s (see Fig. C3)**

Whenever a stationary vehicle is placed on a canted track whose running surface lies at an angle $\delta$ to the horizontal, its body leans on its suspensions and forms an angle $\eta$ with the perpendicular to the rail level. The vehicle flexibility coefficient s is defined by the ratio:

$$s = \frac{\eta}{\delta}$$

This ratio may be calculated or measured (see UIC Leaflet 505-5). It depends in particular on the load state of the vehicle.

**Powered units of constant weight:** Locomotives, etc: Unladen state in running order

**Vehicles with non-constant weight:** Multiple units, coaches, vans, coaches with driving cab, etc.

Unladen state in running order and exceptional load state (maximum load state)

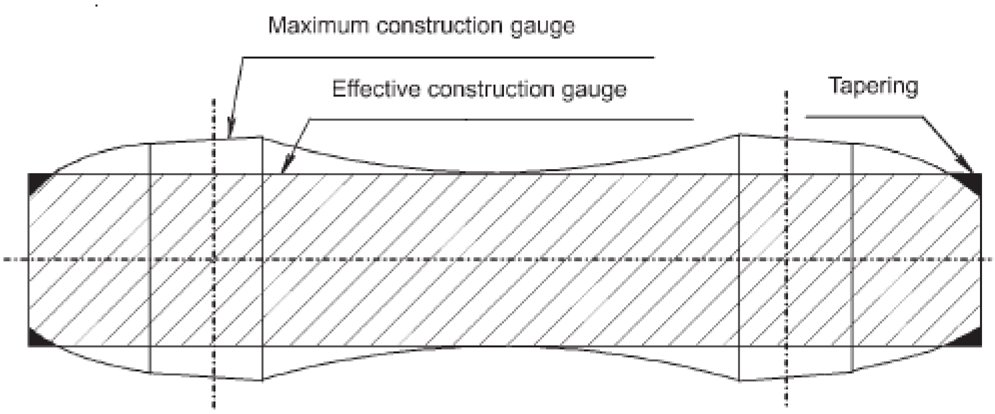
**Vehicles with non-constant weight:** Wagons: Unladen state in running order and maximum load state

**C.2.2.6 Maximum construction gauge for rolling stock**

The maximum construction gauge is the maximum profile, obtained by applying the rules giving reductions in relation to the reference profile, which the various parts of the rolling stock must respect. These reductions depend on the geometric characteristics of the rolling stock in question, the position of the cross-section in relation to the bogie pivot or to the axles, the height of the point considered in relation to the running surface, constructional play, the maximum wear allowance and the elastic characteristics of the suspension.

In general, the effective construction gauge uses only partially the non-hatched areas within the maximum construction gauge for the installation of foot-steps, hand-rails, etc.

*Fig. C4*




**C.2.2.7 Kinematic gauge**

This covers the furthest positions in relation to the centres of the normal co-ordinates likely to be taken by various parts of rolling stock, taking into account the most unfavourable positions of the axles on the track, the lateral play and quasi-static movements attributable to the rolling stock and to the track.

The kinematic gauge does not take account of certain random factors (oscillations, asymmetry, if $\eta o \leq 1^o$): the suspended parts of the vehicles may therefore exceed the kinematic gauge in the course of oscillation. Such movements are taken into account by the Way and Works Department.

**C.2.2.8 Quasi-static movements z**

'z' is the part of lateral movements attributable to the rolling stock (when there is a 50 mm cant deficiency) and resulting from the technology and flexibility of the suspensions (flexibility coefficient s), under the effect of centrifugal force not compensated for by cant or of excessive cant (see Figure 3a or 3b) and under the effect of asymmetry $\eta o$ (see Figure 3c). This value depends on the height h of the point in question.

**C.2.2.9 S projections (Fig.C5)**

Part outside the reference profile when the vehicle is on a curve and/or on track with a gauge wider than 1,435 m.s

The half-width of the vehicle, plus the D movements, minus the half-width of the reference profile at the same level, is equivalent to the actual projection S in relation to the reference profile.

Also see Section 2.3'Permitted projections'.

**C.2.2.10 Ei or Ea reductions**

To ensure that a vehicle when on the track does not exceed the 'vehicle limit position' in view of its D movements, the halfwidth dimensions must be subject to an Ei or Ea reduction, in relation to the reference profile, such that:
Ei or Ea ≥ D – So.

The following distinction is made:

- Ei : reduction value for the reference profile half-width dimensions for the sections located between the end axles of vehicles not mounted on bogies or between the pivots of vehicles mounted on bogies
- Ea : reduction value for the reference profile half-width dimensions for the sections beyond the end axles of vehicles not mounted on bogies or the pivots of vehicles mounted on bogies.

**C.2.2.11 Lineside structure gauge**

Profile in relation to the axes of co-ordinates normal to the track, inside which no structure must penetrate despite elastic or non-elastic track movements.

## C.2.3 GENERAL COMMENTS ON THE METHOD FOR OBTAINING THE MAXIMUM ROLLING STOCK CONSTRUCTION GAUGE

The study of the maximum construction gauge takes into account both the lateral and vertical movements of the rolling stock, drawn up on the basis of the geometrical and suspension characteristics of the vehicle under various loading conditions.

In general, the maximum construction gauge of a vehicle is determined for the ni or na values which correspond to the middle of the vehicle and the headstocks. It is of course necessary to check all the projecting points, as well as those which, in view of their location, are likely to be in close proximity to the vehicle construction maximum gauge within the section under consideration.

Transversally, taking into account the vehicle body movements obtained for a point located on an ni or na section at height h in relation to the running surface, the half-widths of the maximum vehicle construction gauge shall be at the most equal to the corresponding half-widths of the reference profile, specific to each type of vehicle, decreased by the Ei or Ea reductions.

These reductions must satisfy the relationship Ei or Ea ≥ D – So in which:

- D represents the movements whose values are calculated by the formulae given in Para. 1.4.2.
- So represents the maximum projections, the values of which are shown in Para. 2.3 'Permitted projections'.

### C.2.3.1 Relative positions of the various gauges

Fig.C5 shows the position of the various gauges in relation to each other, as well as the main elements involved in determining the rolling stock maximum construction gauge.

*Fig. C5*

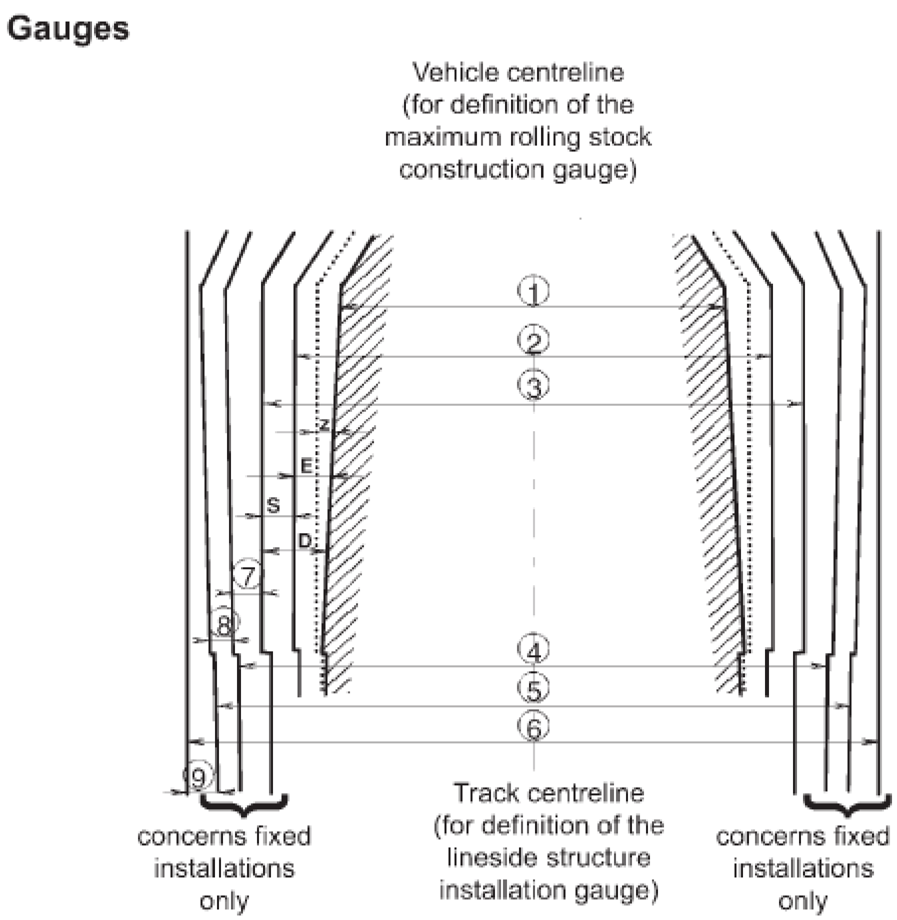


**Figure C5**

① Rolling stock maximum construction gauge

② Kinematic gauge reference profile

③ Limit position of rolling stock considered in the reduction formulae

④ Rolling stock kinematic gauge

⑤ Lineside structure limit gauge

⑥ Lineside structure installation gauge

z = quasi-static movement taken into account in the reduction formulae:
- for a cant excess or deficiency of 0.05 m,
- for that part of the asymmetry exceeding 1°
- for cant excess or deficiency between 0.05 m and 0.2 m maximum which is not taken into account by the Way and Works Department if s > 0.4 and/or $h_c$ < 0.5 m.

E = Reduction ($E_i$ or $E_a$)
S = Lateral projection (for the rolling stock $S_0$ = maximum projection)
D = Lateral movement

⑦ Quasi-static movement due to cant excess or deficiency exceeding 0.05 m (for s = 0.4, $h_c$ = 0.5 m)

⑧ Value added by the Way and Works Department in order to take into account track defects in service, oscillations and asymmetries of ≤1° and resulting movements.

⑨ Margin specific to each Railway in order to take into account special situations (transport of exceptional loads, margins for increasing the speed, high prevailing cross-winds).

## C.2.4 RULES FOR THE REFERENCE PROFILE FOR DETERMINING THE MAXIMUM ROLLING STOCK CONSTRUCTION GAUGE

In order to determine the maximum construction gauge of a vehicle, the Rules for the reference profiles must take account of:

- vertical movements,
- transverse movements.

Construction tolerances are partly taken into account in the asymmetry calculation.

The nominal width value of a vehicle is obtained from the dimensions of the maximum constructional profile.

Tolerance values must not be used systematically to increase vehicle dimensions.

### C.2.4.1 Vertical movements

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

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

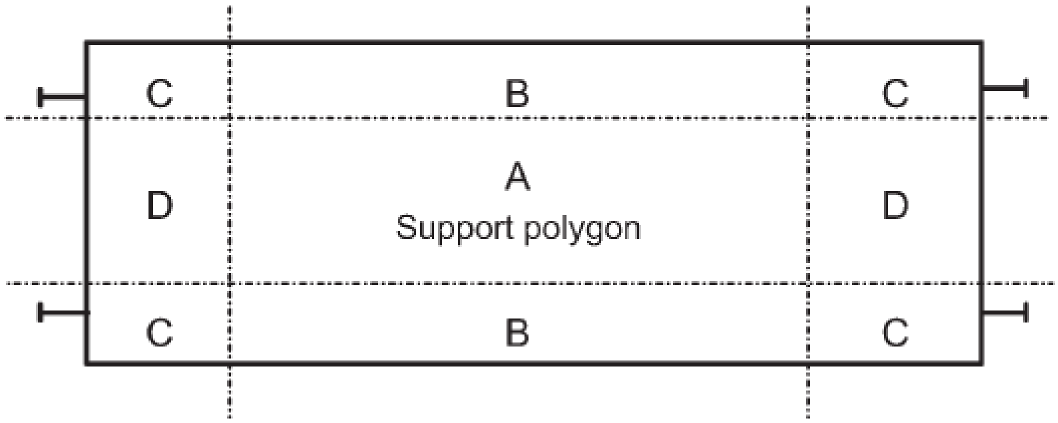
It should be noted that for all parts located at a height greater than 400 mm above the running surface, the vertical component of the quasi-static movements is not taken into account.

#### C.2.4.1.1 Determination of minimum heights above the running surface

The minimum heights above the running surface for parts located towards the lower part of the gauge (1 170 mm and below) are determined with account being taken of the vertical movements described in the following paragraphs.

When studying the sag of the vehicle bodies (also see Appendix 2) the division shown in the diagram below shall be considered.

Fig. C6




Sags independent of the load state and of the suspension state

These deflections shall be considered for all vehicle body zones A, B, C and D, and concern the following parts:

- Wheels : maximum wear for all types of vehicles
- Various parts : maximum wear — Examples: side-bearers, brake rigging, etc, for all vehicles and for each special assembly
- Axle boxes : wear ignored
- Bogie frame : manufacturing tolerances giving rise to deflection in relation to the nominal dimensions: ignored
- Body structures : manufacturing tolerances giving rise to deflection in relation to the nominal dimensions: ignored for all vehicles including all conventional and special wagons.

Deflection dependent on the load state of the vehicles and on the state of their suspension

1 — Structural distortions: sags for all the vehicle body zones A, B, C, and D.

| | | |
|---|---|---|
| — Axles | Deflection ignored | |
| — Bogie frame | Deflection ignored | |
| — Body | Transverse deflection | ignored |
| | Twist | ignored |
| | Longitudinal deflection | ignored for all vehicles, except wagons for which the longitudinal sag must be taken into account under the effect of a maximum load increased by 30 % to take dynamic stresses into consideration. |

2 — Deflection of the suspensions

Types of springs:

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

- Steel spring: Deflection under static load,
  Additional deflection under dynamic stress,
  Deflection due to flexibility tolerances.
- Rubber spring: Same deflections as for steel springs
- Pneumatic spring: Total deflection with cushions deflated (including back-up suspension when it exists)
- Suspension deflection conditions
  - Equal and simultaneous deflections on the suspensions (zones A, B, C and D are concerned).

- ‘Conventional’ wagons: total deflection (bottoming).
- Special wagons: deflection under the effect of a 30 % overload on the sprung weight (in order to make maximum use of the gauge, especially in the case of combined transport or of bulky loads) or total deflection (bottoming).
- Other deflections see Appendix 3.

**C.2.4.1.2 Passing over vertical transition curves (including marshalling yard humps) and overbraking, shunting or stopping devices**

a) Vehicles with a reference profile (part below 130 mm) in accordance with paragraph C.3.2.3

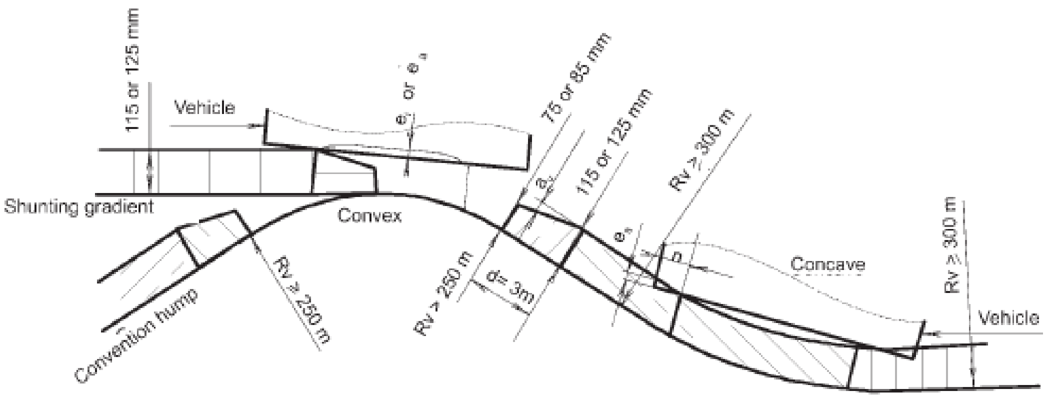
Normal values for the ei or ea vertical reductions to be taken into account for empty coaches, empty or loaded vans and wagons.

These vehicles, when they can be gravity shunted, must be capable of passing over activated rail brakes and other shunting or stopping devices located on non-vertically curved track and reaching the 115 and 125 mm dimensions above the running surface, up to 3 m from the end of convex transition curves of radius Rv ≥ 250 m (dimension d).

They must also be able to pass over such devices located inside or near concave transitions curves of radius Rv ≥ 300 m.

In applying these conditions, the lower dimensions of these vehicles, taking into account vertical movements, assessed as stated in paragraph § 1.4.1, must in relation to the running surface be at least equal to 115 or 125 mm increased by the following ei or ea quantities:

Fig.C7




ei or ea : vertical reduction at the lower part of the rolling stock equipment in relation to the 115 or 125 mm dimensions.

ev : lowering of the rail brakes in relation to the 115 or 125 mm dimensions.

For sections between the end axles or bogie pivots (normal values expressed in metres) The purpose of the numerical index applied to the ei and E'i values is to distinguish the normal values from the reduced values:

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

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

$$e_{i1} = \left[\frac{27}{4} \cdot \frac{n}{a-3}\right]\left[1 - \frac{n}{a-3}\right]^2 \left[\frac{a^2}{3375} - 0{,}04\right] \text{ when } a > 17{,}80 \text{ m and } n < \frac{a-3}{3}$$

$$e_{i1} = \frac{a^2}{3375} - 0{,}04 \text{ when } a > 17{,}80 \text{ m and } n \geq \frac{a-3}{3} \, (^1)$$

**Notes:**

This formula for

$$n \geq \frac{a-3}{3}$$

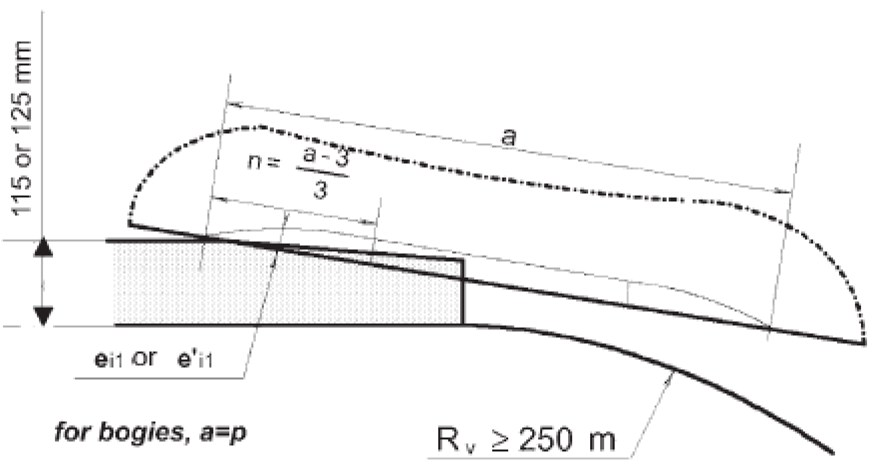
gives reductions greater than or equal to those resulting from the formula for

$$n < \frac{a-3}{3}$$

When empty coaches and empty or loaded wagons and vans can be gravity shunted, they must also be able to pass over convex transition curves of radius ≥ 250 m, without any part other than the wheel flange descending below the running surface.

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

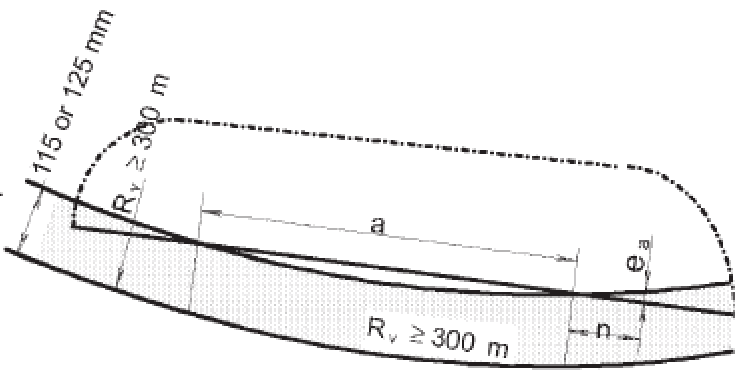
*Fig. C8*




For sections located beyond the end axles or bogie pivots (values in metres)

*Fig. C9*

$$e_a = \frac{an + n^2}{600}$$



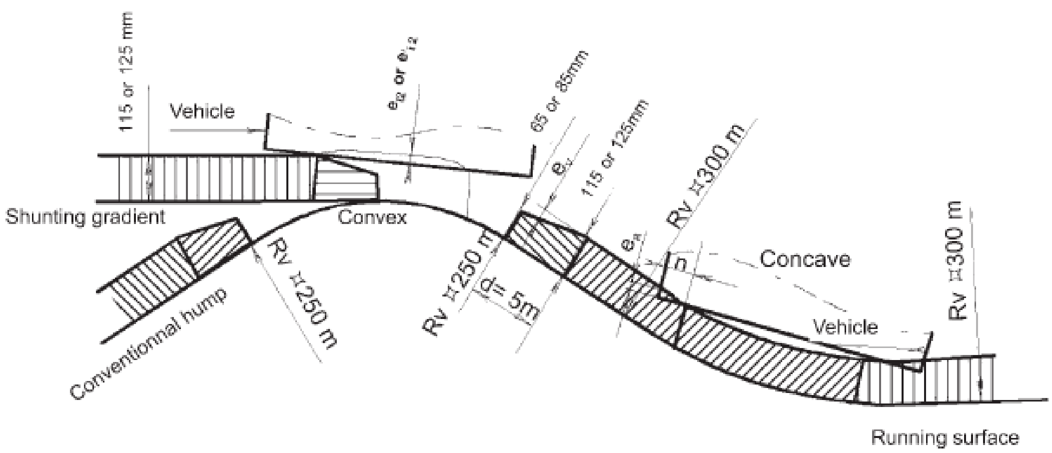

Reduced values for the ei increase (sections between the end axles or bogie pivots) to be considered for certain vehicles for passing over gradient transition curves including shunting humps.

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

Use of these reduced values may require 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 d becomes 5 m.

*Fig. C10*




(reduced values expressed in metres)

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

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

$$e_{i2} \left[\frac{27}{4} \cdot \frac{n}{a-5}\right] \left[1 - \frac{n}{a-5}\right]^2 \left[\frac{a^2}{3375} - 0{,}05\right] \text{ when } a > 15{,}80 \text{ m and } n < \frac{a-5}{3}$$

$$e_{i2} = \frac{a^2}{3375} - 0{,}05 \text{ when } a > 15{,}80 \text{ m and } n \geq \frac{a-5}{3} \; (^1)$$

**Notes:**

(1) This formula for

$$n \geq \frac{a-5}{3}$$

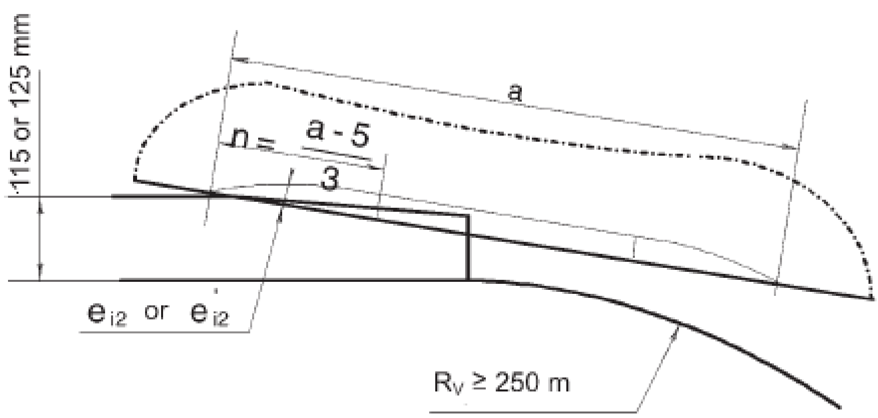
gives reductions greater than or equal to those obtained using the formula for

$$n < \frac{a-5}{3}$$

When they can be gravity shunted, the wagons must 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 descending below the running surface.

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

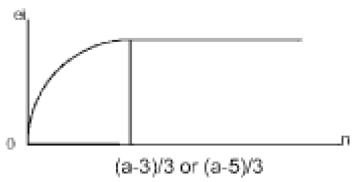
*Fig. C11*




For bogies a = p.

Table C1 showing the values of $E_i$ and $E'_i$ expressed in mm with a and n expressed in m.

| a \ 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 |
| 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 |
| 7 | | | | | | 3 / 0 | 3 / 0 | 3 / 0 | 3 / 0 | 3 / 0 | 3 / 0 | 2 / 0 | 0 / 0 |
| 6.5 | | | | | | | 2 / 0 | 2 / 0 | 2 / 0 | 2 / 0 | 2 / 0 | 1 / 0 | 0 / 0 |
| 6 | | | | | | | | | | 1 / 0 | 1 / 0 | 1 / 0 | 0 / 0 |
| 5.5 | | | | | | | | | | 1 / 0 | 1 / 0 | 1 / 0 | 0 / 0 |
| 5 | | | | | | | | | | 0 / 0 | 0 / 0 | 0 / 0 | 0 / 0 |
| 4.5 | | | | | | | | | | 0 / 0 | 0 / 0 | 0 / 0 | 0 / 0 |




key normal values

reduced values

b) Vehicles not allowed on shunting humps by reason of their length

Empty coaches, wagons suitable for international traffic and empty or loaded vans that are not allowed over marshalling yard humps on account of their length, must nonetheless respect the profile in paragraph C.3.2.3 when placed on a nonvertically curved track, so as to allow for the use of shunting or stopping devices.

c) All vehicles

All vehicles must be able to pass over convex or concave transition curves of radius Rv ≥ 500 m, without any part other than the wheel flange descending below the running surface.

This may concern mainline vehicles whose:

- wheelbase is greater than 17,8 m,
- overhang is greater than 3,4 m.

d) Special cases

Account must be taken of the following particular cases:

- Vertical transition curves for vehicles fitted with the automatic coupler.
- Angle of inclination for vehicles used on ferries.

### C.2.4.1.3 Determination of maximum heights above the running surface

The value of vertical movements to be taken into consideration, as regards the upper parts of rolling stock where h ≥ 3 250 mm, is determined with account being taken of the upward dynamic movements for empty rolling stock in running order without wear.

In this part, the vehicles come close to the reference profile under the influence of:

1) upward oscillations,

2) the vertical component of the quasi-static inclination,

3) transverse movements.

Consequently, the vertical dimensions of the reference profile must be reduced by the values generated by these movements $\xi$, if they can be calculated, or otherwise by a fixed value of 15 mm per suspension stage.

Nevertheless, it must be noted that when the vehicle is subject to quasi-static inclination, the side opposite the inclination rises but at the same time moves away from the reference profile in such a way that no interference is to be feared.

Conversely, on the side of the inclination, the vehicle lowers, thus compensating part of the upward movements.

As an approximation, for cant excess or deficiency of 50 mm, this vertical reduction $\Delta V(h)$ of the reference profile for nominal heights greater than h=3,25 m is expressed as:

$$\Delta V(h) = \xi - \left\{ \frac{\left[\frac{1}{2}LCR(h) - E_{i\ or\ a}\right] s}{30} \right\}$$

where:

$$\frac{1}{2}LCR(h)$$

represents the half-width of the reference profile,

$E_i$ or $E_a$ the transverse reductions,

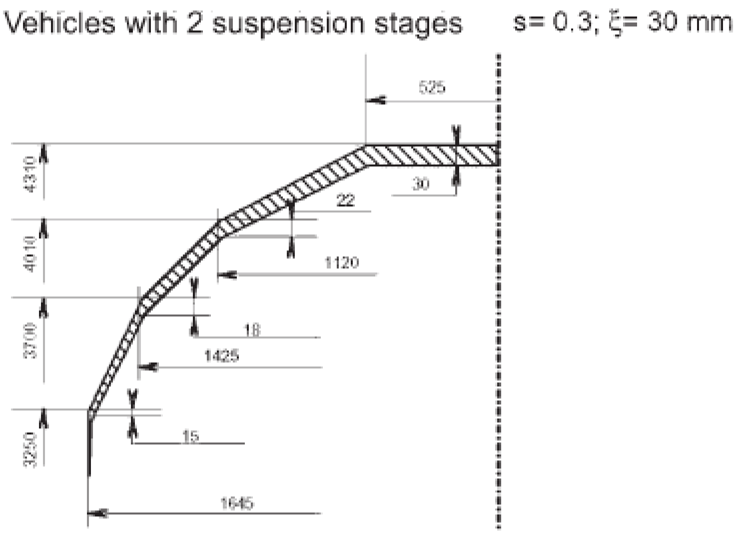
s the vehicle's coefficient of flexibility,

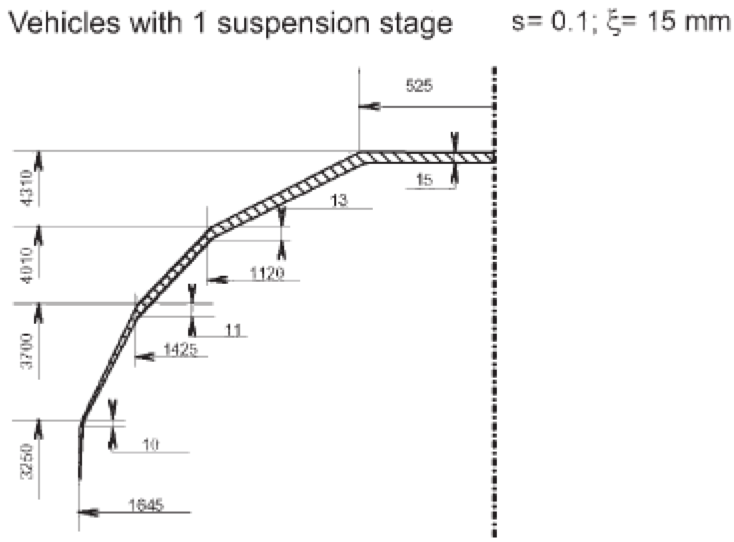
$\xi$ the vehicle resilience (fixed or calculated term).

Example: for a vehicle with a reduction $E_i$ or $E_a$ of 217 mm based on h = 3,25 m, we obtain:

Reductions for cut-away sides on the upper part of the reference profile.

*Fig. C12*




### C.2.4.2 Lateral movements (D)

These movements are the sum of the following movements:

– geometric movements resulting from the vehicle running through curves and straight track (projections, lateral play, etc.), where the vehicle centreline is considered to be perpendicular to the running surface;

– quasi-static movements resulting from the inclination of the suspended parts under the influence of gravity (canted track) and/or centrifugal acceleration (curved track).

– lateral sag of the vehicle body is generally disregarded except for those special types of wagon or heavily-laden wagons for which these values are particularly high.

#### C.2.4.2.1 Vehicle running position on the track and displacement factor (A)

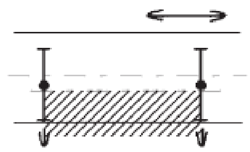
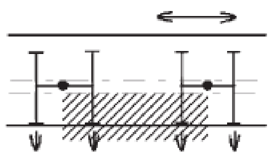
The various vehicle running positions on the track depend on the transverse play of the various parts connecting the vehicle body to the track and on the configuration of the running gear (independent axles, powered bogies, trailer bogies, etc).

It is therefore necessary to consider the various positions which the vehicle may take up on the track so as to take into account any displacement factor A to be applied to certain terms in the fundamental formulae used for calculating the $E_i$ internal and $E_a$ external reductions.

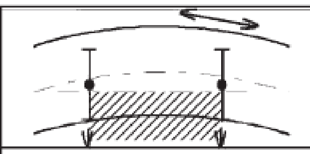
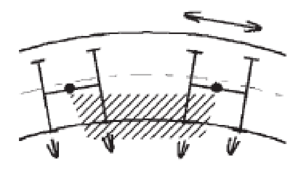
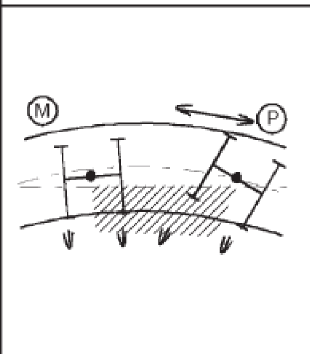
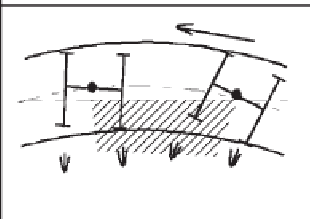
The displacement factor and the vehicle running position on the track are given in the table below. For the cases of axle configuration not represented in the table, the running position conditions to be taken into account must be the least favourable.

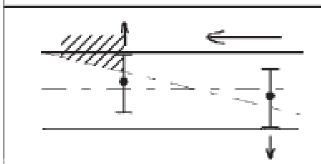
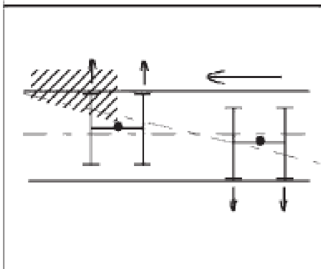
For articulated vehicles, it is recommended to take the running position for conventional 2-bogie vehicles.

Table 2 Displacement factor and vehicle position on the track

| Calculation of internal reductions $E_i$ | | | | | |
|---|---|---|---|---|---|
| Vehicle type | Terms to which A factor applies / Running position on the track | $\frac{1.465 - d}{2}$ | W: on straight track $W_\infty$ | W: depending on curve radius $W_{i(R)}$ | $\frac{p^2}{4}$ (on curve) |
| On straight track | | Displacement factor A | | | |
| 1 2-axle vehicles or bogies taken individually and associated parts |  | 1 | | | |
| 2 2-bogie vehicles except those below |  | 1 | 1 | | |
| 3 Vehicle with on designated "motor" bogie leading and one trailer bogie leading or considered as such | | 1 | $W_\infty$: $\frac{a - n_p}{a}$; $W'_\infty$: $\frac{n_p}{a}$ | | |

*OTIF UTP* | *Corresponding text in EU regulations* [1] | *EU ref.* [2]

| On curve | | Displacement factor A | | | | | |
|---|---|---|---|---|---|---|---|
| 4<br>2-axle vehicles<br>or<br>bogies taken individually<br>and associated parts |  | The running positions and displacement factors for curves are the same as for straight track | | | | | |
| 5<br>Vehicles with 2 motor bogies or designated as "motored" |  | 1 | | 1 | | 1 | |
| 6<br>Vehicles with 1 bogie designated as "motored" (M) and 1 trailer bogie or bogie designated as unpowered (P) |  | $\frac{a - n_\mu}{a}$ | | $W_{i(R)}$<br>$\frac{a - n_\mu}{a}$ | $W'_{i(R)}$<br>$\frac{a - n_\mu}{a}$ | $\frac{p^2}{4}$<br>$\frac{a - n_\mu}{a}$ | $\frac{p^2}{4}$<br>$\frac{a - n_\mu}{a}$ |
| 7<br>Vehicles with 2 trailer bogies or considered as such<br><br>(1) special casefor wagons |  | 0<br><br>0(1) | | 1<br><br>1(1) | | 1<br><br>1(1) | |

| Calculation of the external reductions $E_a$ | | | | | | |
|---|---|---|---|---|---|---|
| Terms to which A factor applies / Running position on the track | $\frac{1{,}465 - d}{2}$ | q | on straight track<br>$W_\infty$ | depending on curve radius<br>$W_{i(R)}$ | $W_{a(R)}$ | $\frac{p^2}{4}$<br>(on curve) |
| **On straight track** | **Displacement factor A** | | | | | |
|  | $\frac{2n+a}{a}$ | $\frac{2n+a}{a}$ | | | | |
|  | $\frac{2n+a}{a}$ | $\frac{2n+a}{a}$ | $\frac{2n+a}{a}$ | | | |
| | $\frac{2n+a}{a}$ | $\frac{2n+a}{a}$ | $W_\infty$ / $W'_\infty$<br>leading motor bogie<br>$\frac{n+a}{a}$ / $\frac{n}{a}$<br>leading trailer bogie<br>$\frac{n}{a}$ / $\frac{n+a}{a}$ | | | |

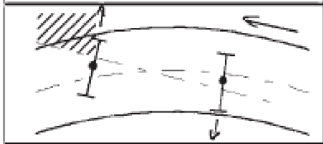
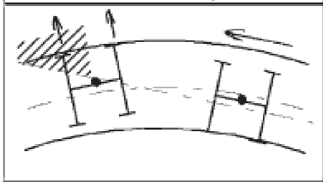
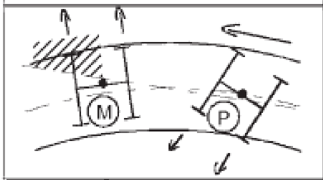
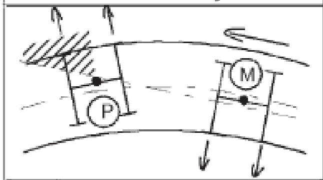
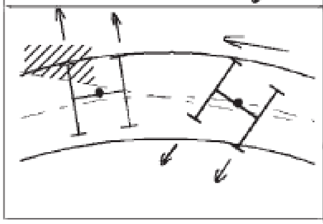
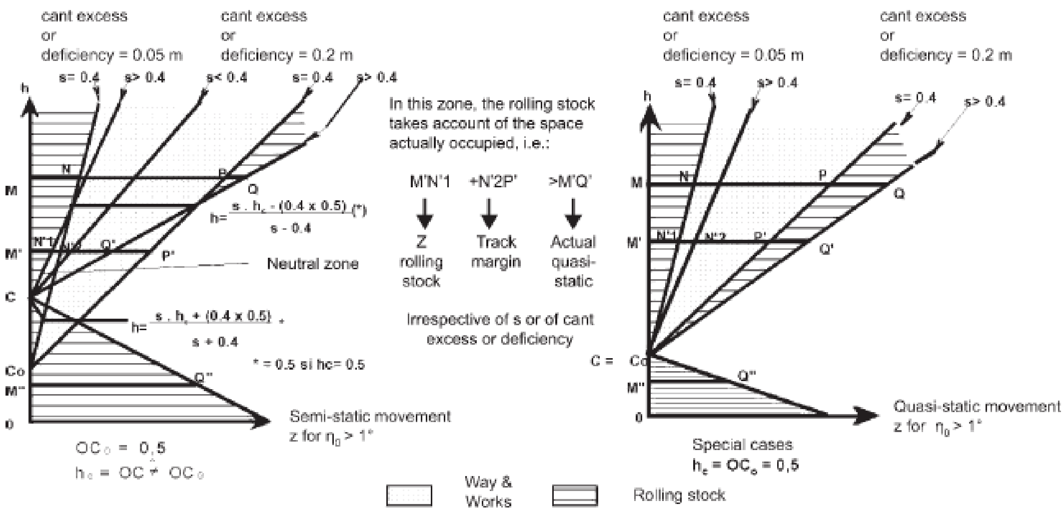
| On curve | Displacement factor A | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
|  | The running positions and displacement factors for curves arethe same as for straight track | | | | | | | | |
|  | $\frac{2n+a}{a}$ | $\frac{2n+a}{a}$ | | $\frac{n}{a}$ | | $\frac{n+a}{a}$ | | 1 | |
| | | | | $W_{i(R)}$ | $W'_{i(R)}$ | $W_{a(R)}$ | $W'_{a(R)}$ | $\frac{p^2}{4}$ | $\frac{p^2}{4}$ |
|  | $\frac{n+a}{a}$ | $\frac{2n+a}{a}$ | | | $\frac{n}{a}$ | $\frac{n+a}{a}$ | | $\frac{n+a}{a}$ | $\frac{n}{a}$ |
|  | $\frac{2n+a}{a}$ | $\frac{2n+a}{a}$ | | $\frac{n}{a}$ | | | $\frac{n+a}{a}$ | $\frac{n}{a}$ | $\frac{n+a}{a}$ |
|  | $\frac{n+a}{a}$ | $\frac{2n+a}{a}$ | | $\frac{n}{a}$ | | $\frac{n+a}{a}$ | | 1 | |
| | $\frac{n+a}{a}$ (1) | $\frac{2n+a}{a}$ (1) | $\frac{2n+a}{a}$ (1) | | | | | 1 (1) | |

*Fig. C13*




## C.2.4.2.2 Special cases of multiple units and coaches fitted with a reversing cab (driving trailer)

For this rolling stock, the bogies are classified according to their adhesion coefficient μ on starting.

| | | |
|---|---|---|
| If $\mu \geq 0,2$ | the bogie is designated | 'motor' |
| If $0 < \mu < 0,2$ | the bogie is considered | 'trailer' |
| If $\mu = 0$ | the bogie is | 'trailer'. |

### C.2.4.2.3 Quasi–static movement (z)

These movements are taken into account when calculating Ei or Ea, depending on the flexibility coefficient s, the height h above the running surface of the point under consideration and the height of the roll centre hc.

The Way and Works Department shall define the lineside clearance gauge for h > 0,5 m, when the effective cant excess or deficiency of the track is greater than 0,05 m calculating in conventional manner the extra quasi-static inclination for rolling stock with a coefficient of flexibility of 0,4 and a roll centre height of 0,5 m.

The Rolling Stock Department shall determine Ei and Ea taking into account:

– a cant excess or deficiency of 0,05 m;
– where appropriate a cant excess or deficiency of 0,2 m, when the respective values of s and hc lead to the gauge defined by the Way and Works Department being exceeded (see figure below and paragraph 1.5.1.3).
– of the influence, beyond 1°, of the asymmetry resulting from design and adjustment (1) tolerances (side-bearers play) and from any unevenness in the distribution of the normal load. The influence of asymmetry less than 1° is taken into account in the lineside clearance gauge, as are the lateral oscillations created randomly by causes inherent both to the rolling stock and track (for resonance phenomena in particular).

| Straight line | Equation | From the equations opposite, infer the lengths of the segments below, the values of which also appear in the 'special cases' in Para. 8.1.3: |
|---|---|---|
| CoN | $z = 0{,}4.0{,}05\left\lvert\frac{h-0{,}5}{1{,}5}\right\rvert$<br>$z = s.0{,}05\left\lvert\frac{h-h_c}{1{,}5}\right\rvert$ | Cant excess or deficiency = 0,05 m<br>$\overline{M'N'_1} = s.0{,}05\frac{h-h_c}{1{,}5} = \frac{s}{30}\lvert h-h_c\rvert$ |
| CN'1 | $z = 0{,}4.0{,}2\left\lvert\frac{h-0{,}5}{1{,}5}\right\rvert$<br>$z = s.0{,}2\left\lvert\frac{h-h_c}{1{,}5}\right\rvert = \frac{4s}{30}\lvert h-h_c\rvert$ | Cant excess or deficiency = 0,2 m<br>$\overline{MQ}$ or $\overline{M''Q''} = \left(\frac{S}{30}+\frac{S}{10}\right)\lvert h-h_c\rvert = \frac{4s}{30}\lvert h-h_c\rvert$ |
| CoP | | $\overline{NP} = 0{,}4(0{,}2-0{,}05)\frac{h-0{,}5}{1{,}5} = 0{,}04(h-0{,}5)$ |
| CQ | | |
| CQ"} | | |

(in the above formulae, dimensions are given in metres)

## C.2.5 DETERMINATION OF REDUCTIONS BY CALCULATION

Reductions $E_i$ and $E_a$ are determined on the basis of the following fundamental relation:

Reduction $E_i$ or $E_a$ = Movement $D_i$ or $D_a$ — Projection $S_o$

Internal reductions

$$E_i = \frac{an_i - n_i^2 + \frac{p^2}{4}(A)}{2R} + \frac{1{,}465 - d}{2}(A) + q + w(A) + z + x_i - S_o$$

and external reductions

$$E_a = \frac{an_a + n_a^2 - \frac{p^2}{4}(A)}{2R} + \frac{1{,}465 - d}{2}(A) + q(A) + w(A) + z + x_a - S_o$$

In these formulae:

- A, displacement factor, describes the position of the axles on the track. Values for A are given in paragraph (see section C.2.4.2.1).
- $D_i$ or $D_a$ is the sum of the movements defined in the following paragraph.
- $S_o$ is the maximum projection.

$x_i$ and $x_a$ are special terms for the calculation for vehicles with very large wheelbase.

### C.2.5.1 Terms taken into account in calculating movements (D)

In view of the particular features of each type of vehicle, additional terms are necessary and some parameters may alter the following terms:

#### C.2.5.1.1 Terms concerning the running position of the vehicle on a curve (geometric overthrow)

$$\frac{1}{2R}\left(an_i - n_i^2 + \frac{p^2}{4}\right)$$

= Geometric overthrow of a given section towards the inside of a curve of radius R (problem of vehicle body sections located on inside of bogie pivots or of axles).

$$\frac{1}{2R}\left(an_a + n_a^2 - \frac{p^2}{4}\right)$$

= Geometric overthrow of a given section towards the outside of a curve of radius R (problem of vehicle body sections located on outside of bogie pivots or of axles)

**Note:**

for special vehicles with particular bogie configurations, these formulae may need to be adapted.

#### C.2.5.1.2 Group of terms concerning lateral play

The value of all these plays is measured at right angles to the axles or pivots, with all parts at wear limit.

The vehicle running positions on the track, as shown in paragraph 7.2.2, enable the play to be taken into account in the formulae and the value of the displacement coefficient applicable to be determined, in order to calculate their effect on the section considered.

$$\frac{1{,}465 - d}{2}$$

= play of the axle in the track

q = play between axles and underframe and/or between axle and vehicle body. In other words, the lateral movement between axle-boxes and journals, plus that between the underframe and axle-boxes from the central position and on each side.

w = play of bogie pivots or bolsters. This is the possible lateral movement of the bogie pivots or bolsters, from the central position and on each side, or, for vehicles without a pivot, the possible lateral movement of the vehicle body in relation to the bogie frame, from the central position and depending on the curve radius and the direction of movement.

If the value of w varies with the curve radius:

- $w_i(R)$ means that w is considered for radius R and the inside of the curve;
- $w_a(R)$ means that w is considered for radius R and the outside of the curve;
- $w_\infty$ means that w is considered for straight track.

According to the specific features of each type of vehicle, this term may be rotated: w', $w_i$, $w'_i$, etc. It can also be equal to the sum of some of these notations: $w_i + w_a$, etc, each of these terms being potentially influenced by the corresponding displacement factor.

**C.2.5.1.3 Quasi-static movements (term concerning vehicle ['s ] inclination [learning] on its suspension and its asymmetry when this is greater than 1°)**

Paragraph C.2.4.2.3. 'Quasi-static movements' gives a chart showing the different parts making up the term z

z = deviation from the track central position. This deviation is equal to the sum of 2 terms :

$$\frac{s}{30}|h - h_c|$$

: term concerning the inclination due to the suspension (lateral movement due to the flexibility of the suspension, under the influence of cant excess or deficiency of 0,05 m);

$$\tan[\eta_0 - 1^\circ]|h - h_c|$$

: term concerning the asymmetry, (lateral movement due to that part of the asymmetry exceeding 1)

This sum may be increased by:

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

term integrating cant excess or deficiency of 0,2 m and applicable under the conditions defined in paragraph C.2.4.2.3.

For sprung parts located at height h, the above terms give, in the formulae, a value of:

$$z = \left[\frac{s}{30} + \tan[\eta_0 - 1^\circ]_{>0}\right]|h - h_c| + \left[\frac{s}{10}|h - h_c| - 0{,}04[h - 0{,}5]_{>0}\right]_{>0}$$

a) Special cases

- when

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

- when

$$\left\{\begin{array}{l} h < 0{,}5 \text{ m} \\ \eta_0 \leq 1^\circ \\ \text{and for any value of hc and s} \end{array}\right\} \quad z = \frac{4s}{30}|h_c - h|$$

- when h = hc z = 0

For unsprung parts z = 0.

b) Influence of side-bearers play for wagons fitted with bogies

- For wagons fitted with bogies whose side-bearers play is less than or equal to 5 mm, the $1_\circ$ angle of asymmetry is considered to cover this play and the formula $\eta_0 = 1_\circ$ is conventionally used.

The term 'z' taking into account side-bearers play less than or equal to 5 mm is given as:

$$z = \left[\frac{s}{30}\right]|h-h_c| + \left[\frac{s}{10}|h-h_c| - 0{,}04[h-0{,}5]_{>0}\right]_{>0}$$

and account must be taken of the special cases described above.

– For wagons fitted with bogies whose side-bearers play is greater than 5 mm, account should be taken of the additional inclination α of the vehicle body, expressed as follows:

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

This additional inclination α leads to compression of the suspension which, when multiplied by the coefficient of flexibility s, is given as a rotation of the vehicle body: αs (where s is the coefficient of flexibility).

The total additional inclination may be expressed as:

$$\alpha\,(1 + s)$$

The term z taking account of side-bearers play greater than 5 mm becomes:

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

Note:

$$[\,]_{>0}$$

means that the expression between the square brackets should be taken as its own value if that value is positive or as 0 if that value is negative or null.

$$\eta'_0$$

= asymmetry in the case of 5 mm side-bearers play.

c) Special terms $x_i$ and $x_a$

Terms representing the correction to be made to certain formulae used to calculate the reductions $E_i$ and $E_a$ for the parts distant from the pivots of vehicles with a very large wheelbase and/or very large overhang in order to limit space requirement in curves of radius between 250 m and 150 m:

It will be noted that:

– $x_i$ only enters the formulae if

$$\frac{a^2 + p^2}{4} > 100$$

, i.e. an approximate value for a of 20 m;

– xa only applies if

$$an_a + n_a^2 - \frac{p^2}{4} > 120$$

(exceptional case)

Special condition for $x_a$:

The term xa is not used in the calculation of reductions applicable to vehicles whose overhang respects the conditions laid down for the automatic coupler.

## C.3 GAUGE G1

In 1991 the decision was taken that the regulations for static gauge should no longer be used for the construction of wagons.

The static gauge regulations therefore remain applicable only to the gauges specially defined for loads, which was the case for example with gauges GA, GB, GB1,GB2 and

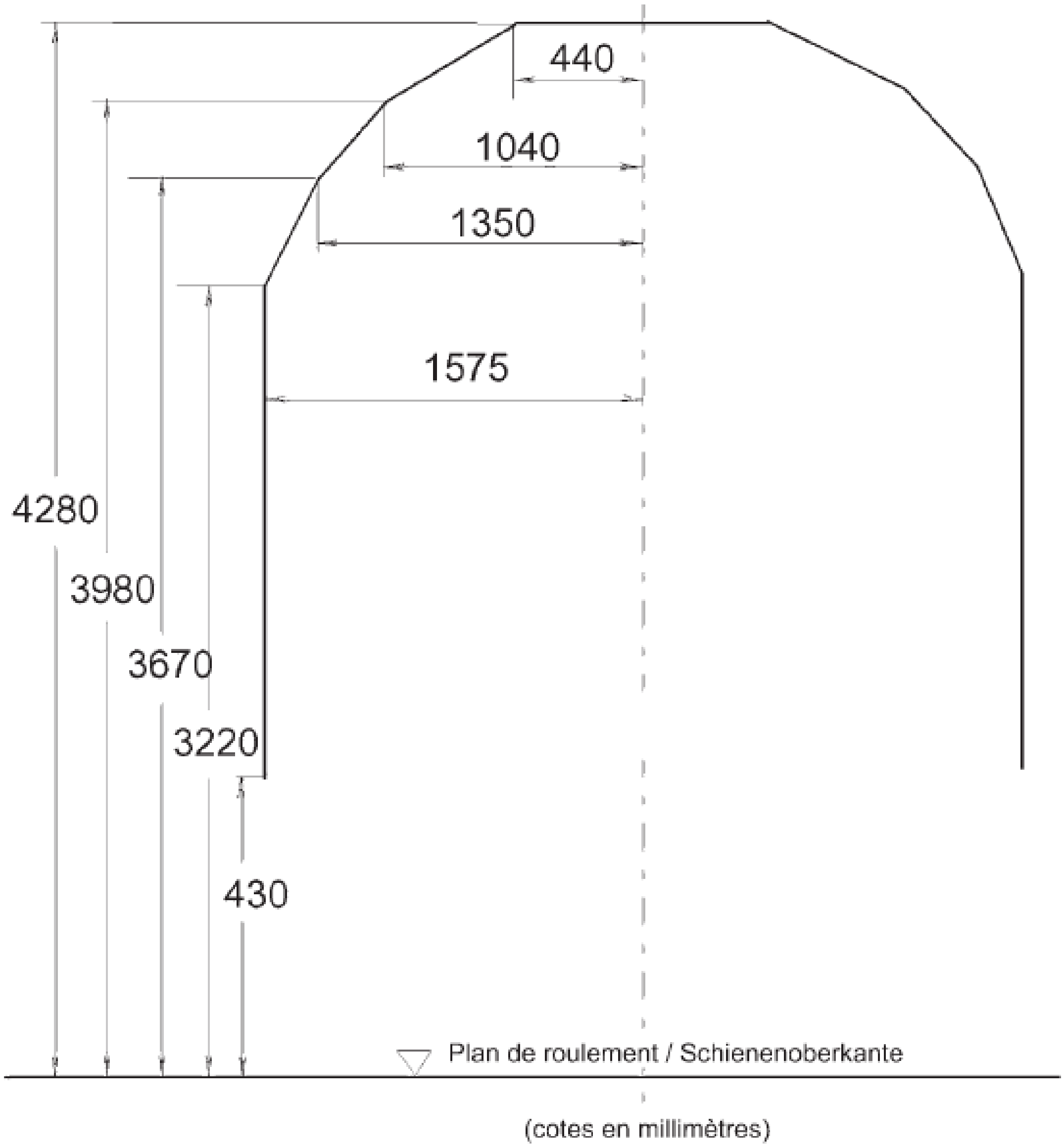
GC.

Static gauge regulations mentioned below include:

1. a reference profile (upper sections),
2. reduction formulae linked with this profile.

## C.3.1 REFERENCE PROFILE FOR STATIC GAUGE G1

*Fig. C14*




### C.3.1.1 Reduction formulae

Sections between the end axles or the bogie pivots

$$E_i = \left[\frac{\Delta_i}{500} + \frac{1{,}465 - d}{2} + q + w + x_{i>0} - 0{,}075\right] > 0$$

$$\text{with: } \Delta_i = 7{,}5 \text{ if } \left(an - n^2 + \frac{p^2}{4} \leq 7{,}5\right)$$

$$\Delta_i = \left(an - n^2 + \frac{p^2}{4}\right) \text{ if this quantity} > 7{,}5$$

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right)$$

Sections situated beyond the end axles or the bogie pivots

$$E_a = \left[\frac{D_a}{500} + \left(\frac{1{,}465 - d}{2} + q + w\right)\frac{2n + a}{a} + [x_a]_{>0} - 0{,}075\right] > 0$$

$$\text{with } \Delta_a = 7{,}5 \text{ if } \left(an + n^2 - \frac{p^2}{4}\right) \leq 7{,}5$$

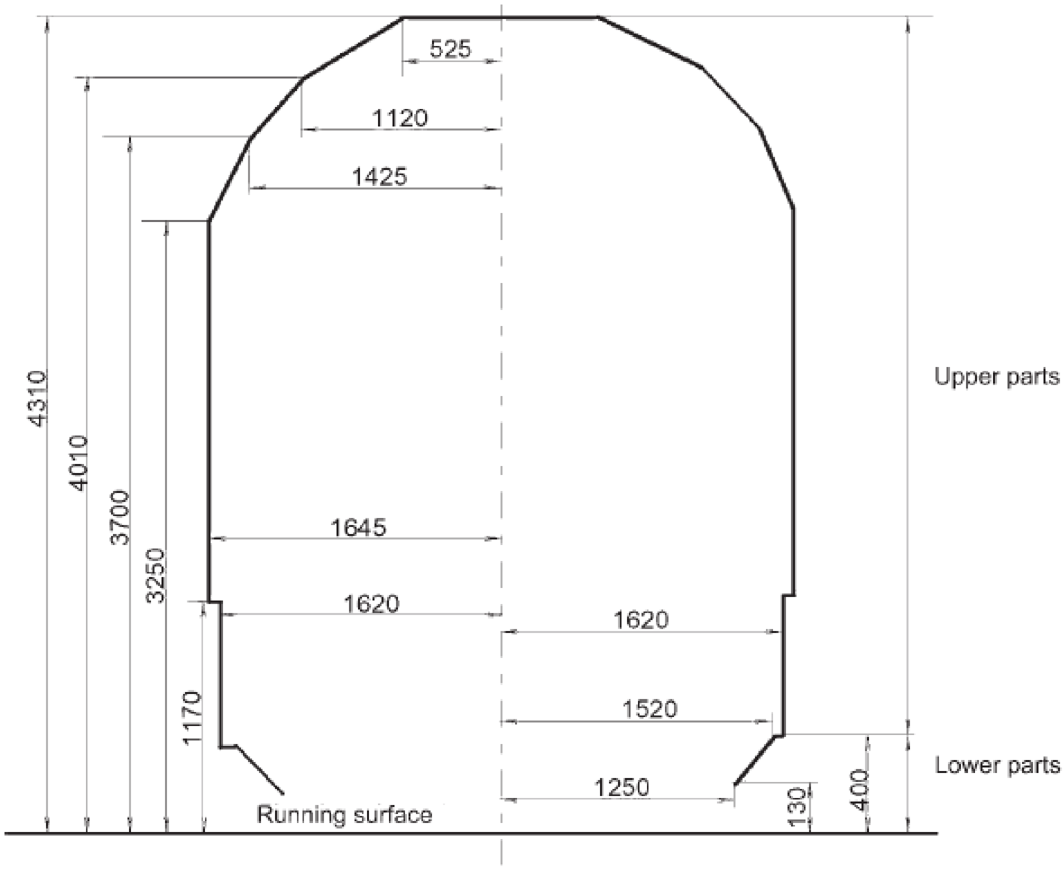
$$\Delta_a = \left(an + n^2 - \frac{p^2}{4}\right) \text{if this quantity is} > 7{,}5$$

$$x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - 120\right)$$

## C.3.2 REFERENCE PROFILE FOR KINEMATIC GAUGE G1

### C.3.2.1 Part common to all vehicles

*Fig. C15*




The G1 kinematic reference profile takes into account the most restrictive lineside structure positions and track centre distances in Continental Europe.

It is divided into 2 parts as follows, one being above and the other below the 400 mm height that is also the limit for the calculation of projections:

- an upper part defined as being above a plane located 400 mm above the running surface, common to all vehicles,
- a lower part defined as being located at or below the plane located 400 mm above the running surface and which differs according to whether the vehicles must pass over shunting bumps, rail brakes and other activated shunting and stopping devices (part lower than 130 mm) or not.

The part below 130 mm differs according to vehicle type.

Loaded coaches must respect the provisions of paragraph C.3.2.2 when on a track without vertical curvature.

Vans and wagons, whether empty or loaded, except for well-wagons and certain combined transport wagons, must satisfy paragraph C.3.2.3.

In the case of wagons intended to run in transit on the Finnish network, the elements of the lower parts must respect the gauge in accordance with the specific standards.

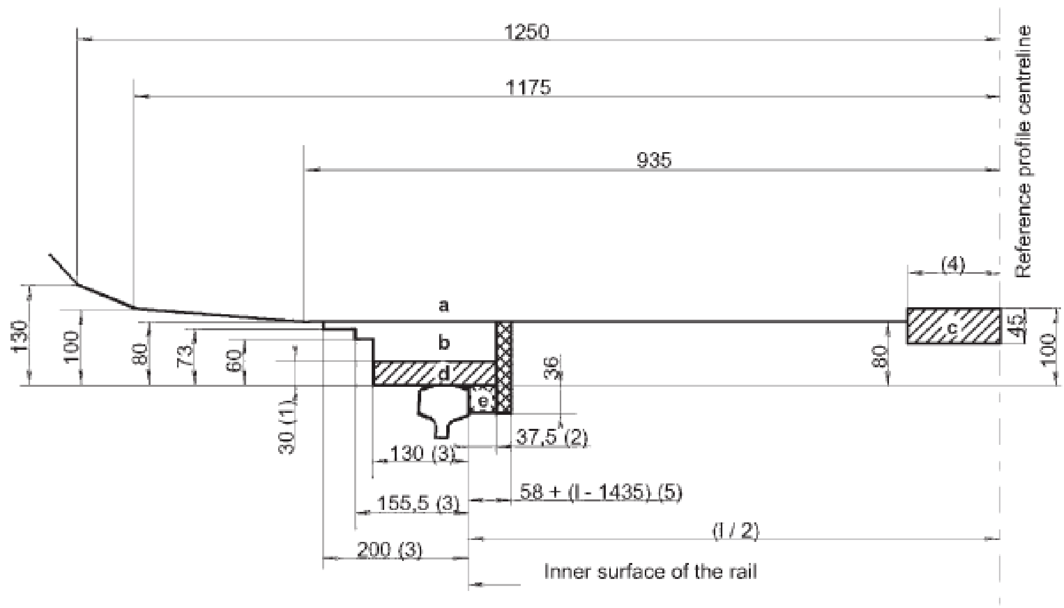
Wagons which must not pass over shunting humps with a curvature radius of 250 m or track brakes and other shunting and stopping devices:

- shall not be allowed to carry the RIV sign, unless otherwise expressly specified in the standards
- are required to bear the inscription to that effect.

### C.3.2.2 Part below 130 mm on vehicles which must not pass over shunting humps or negotiate rail brakes and other activated shunting and stopping devices

Certain gauge restrictions must be observed at right angles to the axles when vehicles are placed on an under-floor wheel lathe for wheel reprofiling.

*Fig. C16*




(Dimensions in millimetres)

a) zone for equipment away from wheels

b) zone for equipment in immediate proximity of 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 axle ends (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) Maximum theoretical width of the flange profile in the case of check-rails.

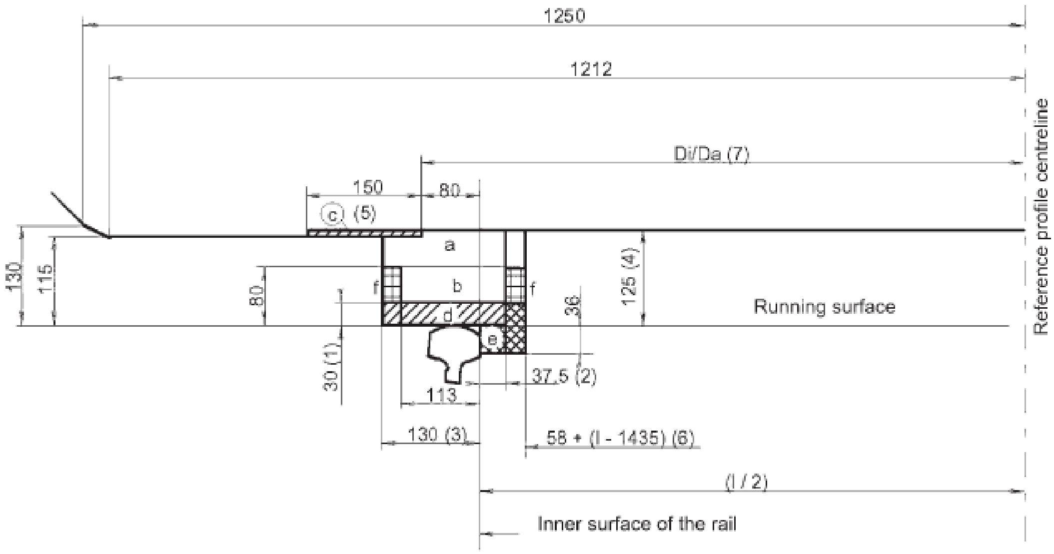
3) Effective limit position of the outside surface of the wheel and of the parts associated with this wheel.

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 width of 1 465 mm, no part of the vehicle likely to descend to less than 100 mm from the running surface, except for the contact brush, should be less than 125 mm from the track centre. For parts located inside the bogies, this dimension is 150 mm.

5) Effective limit position of the internal surface of the wheel when the axle is against the opposite rail. This dimension varies with gauge widening.

### C.3.2.3 Part below 130 mm for vehicles able to pass over shunting humps and negotiate rail brakes and other activated shunting and stopping devices

*Fig. C17*




(Dimensions in millimetres)

a) zone for equipment away from wheels

b) zone for equipment in immediate proximity of wheels

c) zone for ejection of standardised drag shoes

d) zone for wheels and other equipment 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 axle ends (guard-irons, sanders, etc) not to be exceeded for running over detonators.

(2) Maximum fictional width of the flange profiles in the case of check rails.

(3) Effective limit position of the wheel external surface and of the parts associated with the wheel.

(4) This dimension also shows the maximum height of standard drag shoes used for scotching or slowing down the rolling stock.

(5) No rolling stock equipment should penetrate into this area.

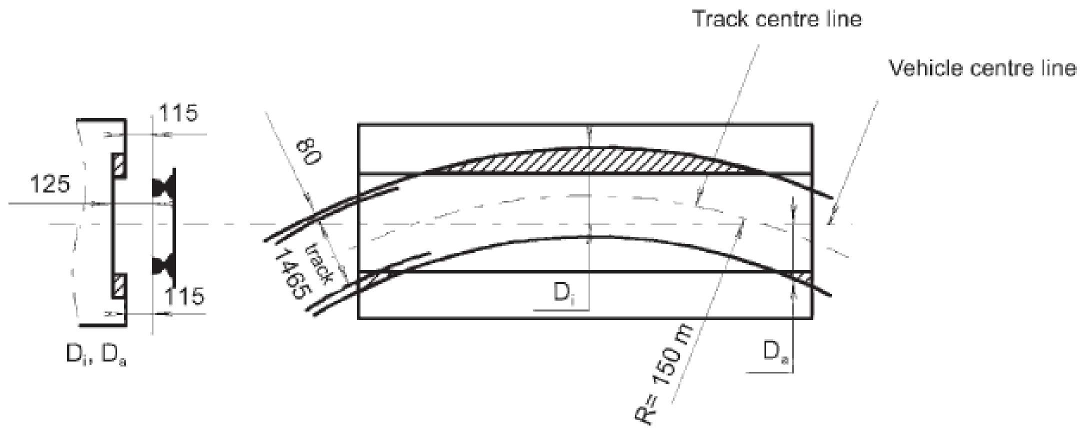
(6) Effective limit position of the wheel internal surface when the axle is against the opposite rail. This dimension varies with gauge widening.

(7) See paragraph on ‘Use of shunting devices on curved track section’.

### C.3.2.3.1 Use of shunting devices on curved track sections

Rail brakes and other shunting and stopping devices which, when activated, can reach the dimensions 115 or 125 mm, in particular drag shoes 125 mm high, may be placed on curves of radius R ≥ 150 m.

*Fig. C18*




(unless otherwise indicated, dimensions are in millimetres)

It follows that the application limit for the 115 or 125 mm dimensions, which is at a constant distance from the inner edge of the rail (80 mm), is at a variable distance D from the centreline of the vehicle, as shown in figure 17 above.

Take the following: (1) (values given in metres)

$$D_i = 0{,}008 + 1{,}465 - \frac{1{,}410}{2} + \frac{an - n^2 + \frac{p^2}{4}}{300} = 0{,}840 + \frac{an - n^2 + \frac{p^2}{4}}{300}$$

$$D_a = 0{,}008 + 1{,}465 - \frac{1{,}410}{2} + \frac{an - n^2 - \frac{p^2}{4}}{300} = 0{,}840 + \frac{an + n^2 - \frac{p^2}{4}}{300}$$

**Note:**

(1) In the particular case involving the use of shunting devices, the influence of plays q + w may be considered negligible.

## C.3.3 PERMITTED PROJECTIONS $S_o$ (S)

The S effective projections must not exceed the $S_o$ values in the table below.

$S_0$ projection values (¹)

| Vehicle types | Track | Ei calculation (³) | | Ea calculation (³) | |
|---|---|---|---|---|---|
| | | Sections between the end axles of vehicles not fitted with bogies or between the pivots of bogie vehicles | | Sections beyond the end axles of vehicles not fitted with bogies or beyond the pivots of bogie vehicle | |
| | | h ≤ 0,400 | h > 0,400 | h ≤ 0,400 | h > 0,400 |
| All powered or trailing vehicles | straight | 0,015 | 0,015 | 0,015 | 0,015 |
| Powered vehicles Trailing axle vehicles<br>Bogie taken individually and their associated parts | on 250 curve | 0,025 | 0,030 | 0,025 | 0,030 |
| | on 150 curve | $0{,}025 + \frac{100\ (^2)}{750} = 0{,}1583$ | $0{,}030 + \frac{100\ (^2)}{750} = 0{,}1633$ | $0{,}025 + \frac{120\ (^2)}{750} = 0{,}185$ | $0{,}030 + \frac{120\ (^2)}{750} = 0{,}190$ |

| Vehicle types | Track | Ei calculation (³) | | Ea calculation (³) | |
|---|---|---|---|---|---|
| | | Sections between the end axles of vehicles not fitted with bogies or between the pivots of bogie vehicles | | Sections beyond the end axles of vehicles not fitted with bogies or beyond the pivots of bogie vehicle | |
| | | h ≤ 0,400 | h > 0,400 | h ≤ 0,400 | h > 0,400 |
| Trailing bogie stock or equivalent | on 250 curve | 0,010 | 0,015 | 0,025 | 0,030 |
| | on 150 curve | $0{,}010 + \frac{100\ (^2)}{750} = 0{,}1433$ | $0{,}015 + \frac{100\ (^2)}{750} = 0{,}1483$ | $0{,}025 + \frac{120\ (^2)}{750} = 0{,}185$ | $0{,}030 + \frac{120\ (^2)}{750} = 0{,}190$ |

(¹) These values have been calculated with the l track gauge which leads to the most restrictive E reduction. This value is $L = l_{max.} = 1{,}465$ m in all cases except for the $E_i$ international reduction for trailing bogie stock or equivalent vehicles for which it is necessary to take lmin = 1,435 m. Furthermore, for powered units and railcars with one designated 'motor' bogie and one trailer bogie or bogie considered as a 'trailer' (see paragraph 7.2.2.1), the width of the track considered in the internal reduction Ei formulae is 1,435 m for the trailer bogie and 1,465 m for the motor bogie. However, for the sake of simplicity in calculating reductions graphically the following values may be taken for both bogies: l = 1,435 m on straight track and 1,465 m on a 250 m curve. In this latter case, the width of the vehicle body is penalised at right angles to the trailer bogie.

(²) Term $x_i$ or $x_a$ in the reduction formulae.

(³) These values do not apply to the reference profile for parts on the roof.

## C.3.4 REDUCTION FORMULAE

**Remark:**

The formulae below must be used to calculate the gauging of articulated vehicles whose wheelset or bogie pivot centrelines coincide with the articulation centrelines of the their bodies. For other articulated vehicle architectures the formulae must be adapted to the actual geometrical conditions.

### C.3.4.1 Reduction formulae applicable to powered vehicles (dimensions in metres)

Powered vehicles for which play w is independent of the track position or varies linearly with the curvature

Internal reductions Ei (where $n = n_i$)

Sections between the end axles of powered vehicles not fitted with bogies or between the pivots of powered bogie vehicles.

when

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) \leq |^{5\,(^1)}_{7,5\,(^2)}$$

position on straight track preponderant:

$$E_i = \frac{1{,}465 - d}{2} + q + w_\infty + z - 0{,}015 \qquad (101)$$

when

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) > |^{5\,(^1)}_{7,5\,(^2)}$$

position on curve preponderant:

$$E_i = \frac{an - n^2 + \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2} + q + w_{i(250)} + z + [x_i]_{>0} - |^{0{,}025\,(^1)}_{0{,}030\,(^2)} \qquad (102)$$

with

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right) + w_{i(150)} - w_{i(250)} \qquad (103)$$

External reductions $E_a$ (where $n = n_a$)

Sections beyond the end axles of powered vehicles not fitted with bogies or the pivots or powered bogie vehicles.

when

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(w_\infty - w_{i(250)}\right)\frac{n}{a} + \left(w_\infty - w_{a(250)}\right)\frac{n+a}{a}\right] \leq |^{5\,(^1)}_{7,5\,(^2)}$$

position on straight track preponderant:

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \qquad (106)$$

when

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(w_\infty - w_{i(250)}\right)\frac{n}{a} + \left(w_\infty - w_{a(250)}\right)\frac{n+a}{a}\right] > |^{5\,(^1)}_{7,5\,(^2)}$$

position on curve preponderant:

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \left(\frac{1{,}465 - d}{a} + q\right)\frac{2n + a}{a} + w_{i(250)}\frac{n}{a} + w_{a(250)}\frac{n+a}{a} + z + [x_a]_{>0} - |^{0{,}025(1)}_{0{,}030(2)} \qquad (107)$$

with

$$x_a = \frac{1}{750}\left(an - n^2 - \frac{p^2}{4} - 120\right) + \left(w_{i(150)} - w_{i(250)}\right)\frac{n}{a} + \left(w_{a(150)} - w_{a(250)}\right)\frac{n+a}{a} \qquad (108)$$

**Notes:**

(1) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

(2) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above

Powered units for which travel w varies non-linearly depending on the curvature (exceptional case)

- Other than curves of radius R 150 and 250 m for which formulae (104), (105) and (109), (110) are identical to formulae (101), (102) and (106), (107) respectively, formulae (104), (105), (109) and (110) must be applied for the value of R for which the variation of w as a function of $\frac{1}{R}$ shows a discontinuity; in other words the value of R as from which the variable stops come into play.
- For each section of the powered unit, the reduction to be taken is the greatest of those obtained from the application of the formulae, in which the value of R to be used is that which gives the highest value for the part between square brackets.

Internal reduction Ei (where n = $n_i$)

when

$\infty > R \geq 250$

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - \left|^{5(1)}_{7,5(2)}\right.}{2R} + w_{i(R)}\right] + \frac{1{,}465 - d}{2} + q + z - 0{,}015 \qquad (104)$$

when

$250 > R \geq 150$

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 100}{2R} + w_{i(R)}\right] + \frac{1{,}465 - d}{2} + q + z + \left|^{0{,}175\,(^1)}_{0{,}170\,(^2)}\right. \qquad (105)\ (^3)$$

External reduction Ea (where n = na)

when

$\infty > R \geq 250$

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - \left|^{5(1)}_{7,5(2)}\right.}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z - 0{,}015 \qquad (109)$$

when

$250 > R \geq 150$

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - 120}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z + \left|^{0{,}215(1)}_{0{,}210(2)}\right. \qquad (110)\ (^3)$$

**Notes:**

(1) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements assessed.

(2) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

(3) In practice, formulae (105) and (110) are without effect, since variation of travel w takes effect when R > 250 through the effect of variable stops.

### C.3.4.2 Reduction formulae applicable to multiple units (dimensions in metres)

For multiple units with one motor bogie and one trailer bogie (see table below)

| Multiple units fitted with : | Values of μ for each of the bogies | Running positions § 2.4.2.2 | Reduction formulae |
|---|---|---|---|
| 2 motor bogies<br>2 bogies considered as 'trailer' bogies | $\mu \geq 0{,}2$<br>$0 < \mu < 0{,}2$ | cases 2 and 5<br>cases 2 and 7 | § 3.4.1<br>§ 3.4.3 |
| one bogie considered as 'trailer' bogie<br>and one trailer bogie | $0 < \mu < 0{,}2$<br>$\mu = 0$ | | |
| one motor bogie and<br>one trailer bogie<br>or considered as 'trailer' bogie | $\mu \geq 0{,}2$<br>$\mu = 0$<br>$0 < \mu < 0{,}2$ | cases 3 and 6 | § 3.4.2 (3)<br>or<br>§ 3.4.1 (3) |

Internal reductions Ei [(4)]

Sections between bogie pivots

$$E_i = \frac{1{,}465 - d}{2} + q + w_\infty \frac{a - n_\mu}{a} + w'_\infty \frac{n_\mu}{a} + z - 0{,}015 \qquad (101a)$$

$$E_i = \frac{a n_\mu - n_\mu^2 + \frac{p^2}{4}.\frac{a - n_\mu}{a} + \frac{p^2}{4}.\frac{n_\mu}{a}}{500} + \frac{1{,}465 - d}{2}.\frac{a - n_\mu}{a} + q + w_{i(250)}\frac{a - n_\mu}{a} + w'_{i(250)}\frac{n_\mu}{a} + z + [x_i]_{>0} - \left|\begin{matrix}0{,}010(1)\\0{,}015(2)\end{matrix}\right. - 0{,}015\frac{a - n_\mu}{a} \qquad (102a)$$

$$\text{with } x_i = \frac{1}{750}\left[a n_\mu - n_\mu^2 - \frac{p^2}{4}.\frac{a - n_\mu}{a} + \frac{p'^2}{4}.\frac{n_\mu}{a} - 100\right] + \left(w_{i(150)} - w_{i(250)}\right)\frac{a - n_\mu}{a} + \left(w'_{i(150)} - w'_{i(250)}\right)\frac{n_\mu}{a} \qquad (103a)$$

**Notes:**

(3) The results of the formulae in paragraphs 3.4.1 and 3.4.2 are very similar; as a result, the formulae in paragraph 2.4.1 are generally employed, those of paragraph 3.4.2 being reserved for cases where the increased reduction obtained on the half-width of the maximum construction gauge is particularly significant (0 to 12,5 mm according to the vehicle section considered).

(4) The reduction to apply for a given value of n is the greatest reduction obtained from the following formulae:

- (101 a) or (102 a) and (103 a);
- (106 a) or (107 a) and (108 a);
- (106 b) or (107 b) and (108 b).

External reductions $E_a$ [(4)] motor bogie end (at the front in the running direction)

Sections beyond the bogie pivots (where $n = n_a$)

$$E_a = \left[\frac{1{,}465 - d}{2} + q\right]\frac{2n + a}{a} + w_\infty \frac{n + a}{a} + w'_\infty \frac{n}{a} + z - 0{,}015 \qquad (106a)$$

$$E_a = \frac{a n + n^2 - \frac{p^2}{4}.\frac{n + a}{a} + \frac{p'^2}{4}.\frac{n}{a}}{500} + \frac{1{,}465 - d}{2}.\frac{n + a}{a} + q\frac{2n + a}{a} + w'_{i(250)}\frac{n}{a} + w_{a(250)}\frac{n + a}{a} + z + [x_a]_{>0} - \left|\begin{matrix}0{,}025\,(^1)\\0{,}030\,(^2)\end{matrix}\right. \qquad (107a)$$

$$\text{with } x_a = \frac{1}{750}\left[a n + n^2 - \frac{p^2}{4}.\frac{n + a}{a} + \frac{p'^2}{4}.\frac{n}{a} - 120\right] + \left(w'_{i(150)} - w'_{i(250)}\right)\frac{n}{a} + \left(w_{a(250)} - w_{a(250)}\right)\frac{n + a}{a} \qquad (108a)$$

External reductions Ea [(4)] trailer bogie end (at the front in the running direction)

Sections beyond the bogie pivots (where $n = n_a$)

$$E_a = \left[\frac{1,465 - d}{2} + q\right]\frac{2n + a}{a} + w_{\infty}\frac{n}{a} + w'_{\infty}\frac{n + a}{a} + z - 0,015 \qquad (106b)$$

$$E_a = \frac{an + n^2 + \frac{p^2}{4}\cdot\frac{n}{a} - \frac{p'^2}{4}\cdot\frac{n + a}{a}}{500} + \left(\frac{1,465 - d}{2} + q\right)\frac{2n + a}{a} + w_{i(250)}\frac{n}{a} + w'_{a(250)}\frac{n + a}{a} + z + [x_a]_{>0} - \left|{}^{0,025\,(^1)}_{0,030\,(^2)}\right. \qquad (107b)$$

$$\text{with } x_a = \frac{1}{750}\left[an + n^2 + \frac{p^2}{4}\cdot\frac{n}{a} - \frac{p'^2}{4}\cdot\frac{n + a}{a} - 120\right] + \left(w_{i(150)} - w_{i(250)}\right)\frac{n}{a} + \left(w'_{a(250)} - w'_{a(250)}\right)\frac{n + a}{a} \qquad (108b)$$

**Notes:**

($_4$) The reduction to apply for a given value of n is the greatest reduction obtained from the following formulae:

- (101 a) or (102 a) and (103 a);
- (106 a) or (107 a) and (108 a);
- (106 b) or (107 b) and (108 b).

($_1$) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

($_2$) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

### C.3.4.3 Reduction formulae applicable to coaches and passenger vehicles (dimensions in metres)

a) For bogie coaches, with the exception of the bogies themselves and their associated parts

Coaches for which the play w is independent of the track position radius or varies linearly with the track curvature

**Note:**

The formulae below must also be used to calculate the gauging of axle coaches.

Internal reductions $E_i$

Sections between bogie pivots (where n = ni)

when

$$an - n^2 + \frac{p^2}{4} - 500\left(w_{\infty} - w_{i(250)}\right) \leq 250(1,465 - d) - \left|{}^{2,5\,(^1)}_{0\,(^2)}\right.$$

the position on straight track is preponderant:

$$E_i = \frac{1,465 - d}{2} + q + w_{\infty} + z - 0,015 \qquad (201)$$

when

$$an - n^2 + \frac{p^2}{4} - 500\left(w_{\infty} - w_{i(250)}\right) > 250(1,465 - d) - \left|{}^{2,5(1)}_{0(2)}\right.$$

the position on curved track is preponderant:

$$E_i = \frac{an - n^2 + \frac{p^2}{4}}{500} + q + w_{i(250)} + z + [x_i]_{>0} - |^{0{,}010(1)}_{0{,}015(2)} \quad (202)$$

with

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right) + w_{i(150)} - w_{i(250)} \quad (203)$$

**Notes:**

(1) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

(2) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

External reductions Ea

Sections beyond bogie pivots (where n = na)

when

$$an + n^2 - \frac{p^2}{4} - 500\left[(w_\infty - w_{i(250)})\frac{n}{a} + (w_\infty - w_{a(250)})\frac{n+a}{a}\right] \le 250(1{,}465 - d)\frac{n}{a} + |^{5(1)}_{7{,}5(2)}$$

the position on straight track is preponderant:

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n + a}{a} + z - 0{,}015$$

when

$$an + n^2 - \frac{p^2}{4} - 500\left[(w_\infty - w_{i(250)})\frac{n}{a} + (w_\infty - w_{a(250)})\frac{n+a}{a}\right] > 250(1{,}465 - d)\frac{n}{a} + |^{5(1)}_{7{,}5(2)}$$

the position on curved track is preponderant:

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2}\cdot\frac{n+a}{a} + q\frac{2n+a}{a} + w_{i(250)}\frac{n}{a} + w_{a(250)}\frac{n+a}{a} + z + [x_a]_{>0} - |^{0{,}025(1)}_{0{,}030(2)}$$

with

$$x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - 120\right) + (w_{i(150)} - w_{i(250)})\frac{n}{a} + (w_{a(150)} - w_{a(250)})\frac{n+a}{a}$$

**Notes:**

(1) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

(2) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

Coaches for which the play w varies non-linearly with the curvature

On straight track the reductions are calculated using formulae 201 and 206.

On curves, the reductions are calculated for R = 150 m and R = 250 m using formulae (204), (205), (209) and (210).

It should be noted that for a radius of R = 250 m, formulae (204) and (209) are identical, respectively, to formulae (202) and (207).

Furthermore, formulae (204), (205) and (209), (210) must be applied for values of R for which the variation of w, as a function of $\frac{1}{R}$, presents a discontinuity (a step change), i.e. the value of R from which the variable stops come into play.

For each section of the coach, the reduction to be taken is the greatest of those resulting from the application of the abovementioned formulae, in which the value of R to be used is that which gives the highest value for the part between square brackets.

Internal reductions Ei (where n = ni)

When
$\infty > R \geq 250$

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - \left|{}^{5(1)}_{7,5(2)}\right.}{2R} + w_{i(R)}\right] + q + z \qquad (204)$$

When 250 > R ≥ 150

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 100}{2R} + w_{i(R)}\right] + q + z + \left|{}^{0,190\,(^1)}_{0,185\,(^2)}\right. \qquad (205)\ (^3)$$

External reductions Ea (where n = na)

When
$\infty > R \geq 250$

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - \left|{}^{5(1)}_{7,5(2)}\right.}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \frac{1{,}465 - d}{2}\cdot\frac{n+a}{a} + q\frac{2n+a}{a} + z - 0{,}015 \qquad (209)$$

When 250 > R ≥ 150

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - 120}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \frac{1{,}465 - d}{2}\cdot\frac{n+a}{a} + q\frac{2n+a}{a} + z + \left|{}^{0,215\,(^1)}_{0,210\,(^2)}\right. \qquad (210)\ (^3)$$

**Notes:**

(1) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

(2) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

(3) In practice, formulae (205) and (210) have no effect, since the variation in play w, resulting from the variable stops taking effect, begins only when R>250.

b) For bogies and their associated parts

The reduction formulae to be applied are those given in § 4.2.1.8.2. Nonetheless, the distance between the end axles of the bogies is in most cases such that formulae (201) and (206) opposite, identical to formulae (101) and (106), are applicable.

**C.3.4.4 Reduction formulae applicable to wagons (dimensions in metres)**

a) For wagons with independent axles and the bogies themselves and their associated parts (w = 0)

For 2-axle wagons, and only for those parts located below 1,17 m above the running surface, term Z in formulae (301) to (307) may be reduced by 0,005 m when (z-0,005) > 0. It shall be considered nil when (z-0,005) ≤ 0.

1) Internal reductions Ei — Sections between the end axles (where n = ni)

When

$$an - n^2 \leq \Big|^{5(1)}_{7,5(2)}$$

the position on straight track is preponderant:

$$E_i = \frac{1,465 - d}{2} + q + w_\infty + z - 0,015 \qquad (301)$$

When

$$an - n^2 > \Big|^{5(^1)}_{7,5(^2)}$$

the position on curved track is preponderant:

$$E_i = \frac{an - n^2}{500} + \frac{1,465 - d}{2} + q + z - \Big|^{0,025(^1)}_{0,030(^2)} \qquad (302)$$

2) External reductions Ea — Sections beyond the end axles (where n = na)

When

$$an + n^2 \leq \Big|^{5(^1)}_{7,5(^2)}$$

the position on straight track is preponderant:

$$E_a = \left(\frac{1,465 - d}{2}\right)\frac{2n + a}{a} + z - 0,015 \qquad (306)$$

when

$$an + n^2 > \Big|^{5(^1)}_{7,5(^2)}$$

the position on curved track is preponderant:

$$E_a = \frac{an + n^2}{500} + \left(\frac{1,465 - d}{2} + q\right)\frac{2n + a}{a} + z - \Big|^{0,025(^1)}_{0,030(^2)} \qquad (307)$$

**Notes:**

($_1$) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

($_2$) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

b) For bogie wagons

For bogie wagons whose play is considered to be constant, except for the bogies themselves and their associated parts.

Special remark for calculation of z: see § 1.5.1.3.

1) - Internal reductions Ei — Sections between bogie pivots (where n = ni)

When

$$an - n^2 + \frac{p^2}{4} \leq 250(1{,}465 - d) - \Big|^{2{,}5\,(^1)}_{0\,(^2)}$$

the position on straight track is preponderant:

$$E_i = \frac{1{,}465 - d}{2} + q + w_\infty + z - 0{,}015 \qquad (311)$$

When

$$an - n^2 + \frac{p^2}{4} > 250(1{,}465 - d) - \Big|^{2{,}5\,(^1)}_{0\,(^2)}$$

the position on curved track is preponderant:

$$E_i = \frac{an - n^2 + \frac{p^2}{4}}{500} + q + w + z + [x_i]_{>0} - \Big|^{0{,}010\,(^1)}_{0{,}015\,(^2)} \qquad (312)$$

with

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right) \qquad (313)$$

2) External reductions Ea — Sections beyond bogie pivots (where n = na)

when

$$an + n^2 - \frac{p^2}{4} \leq 250(1{,}465 - d)\frac{n}{a} + \Big|^{5\,(^1)}_{7{,}5\,(^2)}$$

the position on straight track is preponderant:

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w\right)\frac{2n + a}{a} + z - 0{,}015 \qquad (316)$$

when

$$an + n^2 - \frac{p^2}{4} > 250(1{,}465 - d)\frac{n}{a} + \Big|^{5\,(^1)}_{7{,}5\,(^2)}$$

the position on curved track is preponderant:

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2} \cdot \frac{n + a}{a} + (q + w)\frac{2n + a}{a} + z + [x_a]_{>0} + \Big|^{0{,}025\,(^1)}_{0{,}030\,(^2)} \qquad (317)$$

with

$$x_i = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - 120\right) \qquad (318)$$

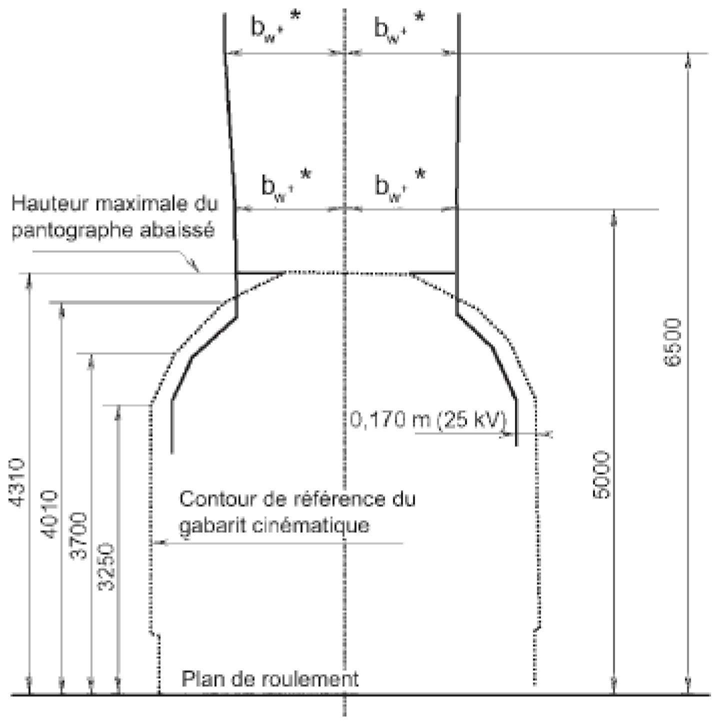
**Notes:**

($_1$) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

($_2$) This value applies to parts located more than 0,400 m above the running surface, with the exception of those covered by footnote (1) above.

## C.3.5 REFERENCE PROFILE FOR PANTOGRAPHS AND NON-INSULATED LIVE PARTS ON THE ROOF

*Figure 19*




Sauf indication contraire, cotes exprimées en millimètres

$b_w$= demi largeur de l'archet

* = déplacements autorisés. Ces déplacements sont respectés lorsque les conditions des formules (111) (112) (113) ou (114) pour h= 6,5 m et (115) (116) (117) ou (118) pour h= 5 m, sont remplies

Espaces dans lesquels ne doivent pas pénétrer les organes non isolés susceptibles de rester sous tension

**Note:**

For vehicles worked on electrified lines, the shaded areas may be used for gauging pantograph bows in the down position.

On non electrified lines, the same possibilities are allowable subject to specific studies by the railways.

## C.3.6 RULES FOR THE REFERENCE PROFILE FOR DETERMINING THE MAXIMUM ROLLING STOCK CONSTRUCTION GAUGE

### C.3.6.1 Powered units fitted with pantographs

Pantograph in current collection position

The present standard is based on the characteristics of pantographs for standard gauge powered units.

In order for powered units with pantographs to respect the limit position resulting from the reference profile, the characteristics of these vehicles (play and coefficient of flexibility of the pantograph-bearing section) and the position of the pantograph in relation to the axles must be such that the quantities E'i and E'a (with pantographs raised to 6,5 m above the running surface) and $E''_i$ and $E''_a$ (pantographs raised to 5 m above the running surface) are negative or nil.

This condition is met if the section in which the pantograph bow is operated is placed close to the transverse centreline of the bogies, i.e. if n is very small or nil.

The limit position is then defined by the reference profile for roof-mounted equipment shown in paragraph 2.5. It corresponds to a maximum geometric overthrow of the pantograph bow of $\frac{2,5}{R}$

a) Preliminary calculations

To determine $E'_i$, $E'_a$, $E''_i$ and $E''_a$, the following preliminary calculations are necessary (1) 1):[3]

$j'i = q + wi - 0{,}0375$ (²) 2)[4]

$$j'_a = q\frac{2n+a}{a} + w_a\frac{n+a}{a} + w_i\frac{n}{a} - 0{,}0375\ (^2)$$

when s ≤ 0,225 (general case)

$$z' = \frac{8}{30}(s-0{,}225) + (t-0{,}03) + (\tau-0{,}01) + 6(\vartheta-0{,}005)$$

but if s > 0,225, this implies a value of

$$z' = \frac{8}{10}(s-0{,}225) + (t-0{,}03) + (\tau-0{,}01) + 6(\vartheta-0{,}005)$$

when s ≤ 0,225 (general case)

$$z'' = \frac{6}{30}s + \sqrt{\left(t\frac{h-h_t}{6{,}5-h_t}\right)^2 + \tau^2 + (\vartheta(h-h_c))^2} - 0{,}0925$$

but if s > 0,225, this implies a value of

$$z'' = \frac{6}{10}s + \sqrt{\left(t\frac{h-h_t}{6{,}5-h_t}\right)^2 + \tau^2 + (\vartheta(h-h_c))^2} - 0{,}1825$$

b) For sections between the end axles or bogie pivots

Expressions for $E'_i$ and $E''_i$ (where $n = n_i$)

When

$$an - n^2 + \frac{p^2}{4} \leq 5$$

the position on straight track is preponderant:

---

[3] For powered units without fixed bogie pivots, see note in § 1.1.

[4] If the play varies according to the track position radius, the maximum value of wi at pivot level (actual or theoretical) shall be taken from j'i, and the maximum value of wa and the corresponding value of wi taken from j'a.

h = 6,5 m $E'_i = j'_i + z'$ (111)

h = 5 m $E''_i = j'_i + z''$ (115)

When

$$an - n^2 + \frac{p^2}{4} > 5$$

the position on curved track is preponderant:

h = 6,5 m

$$E'_i = \frac{an - n^2 + \frac{p^2}{4} - 5}{300} + j'_i + z' \quad (112)$$

h = 5 m

$$E''_i = \frac{an - n^2 + \frac{p^2}{4} - 5}{300} + j'_i + z'' \quad (116)$$

c) For sections beyond the end axles or bogie pivots

Expressions for $E'_a$ and $E''_a$ (where $n = n_a$)

When

$$an - n^2 + \frac{p^2}{4} \leq 5$$

the position on straight track is preponderant:

h = 6,5 m

$$E'_a = j'_a + z' + \frac{1{,}465 - d}{2} \cdot \frac{2n}{a} \quad (113)$$

h = 5 m

$$E''_a = j'_a + z'' + \frac{1{,}465 - d}{2} \cdot \frac{2n}{a} \quad (117)$$

when

$$an - n^2 + \frac{p^2}{4} > 5$$

the position on curved track is preponderant:

h = 6,5 m

$$E'_a = \frac{an + n^2 - \frac{p^2}{4} - 5}{300} + j'_a + z' + \frac{1{,}465 - d}{2} \cdot \frac{2n}{a} \quad (114)$$

h = 5 m

$$E''_a = \frac{an + n^2 - \frac{p^2}{4} - 5}{300} + j'_a + z'' + \frac{1{,}465 - d}{2} \cdot \frac{2n}{a} \quad (118)$$

### C.3.6.2 Railcars fitted with pantographs

The limit position for pantographs on a railcar with one motor bogie and one trailer bogie shall be determined as if both bogies were identical to the one above which the pantograph is placed.

### C.3.6.3 Pantographs in lowered position

Subject, if necessary, to application of the insulation conditions, the lowered pantograph must fall entirely within the gauge defined.

### C.3.6.4 Insulation clearance margin for 25kV

On vehicles which may use a 25 kV power supply, all non-insulated parts likely to remain live must be arranged so as to fall well within the 0,170 m reference profile.

## C.4 GA, GB, GC VEHICLE GAUGES

By comparison with the G1 gauge, the GA, GB and GC gauges are larger in the upper part.

Loads and vehicles conforming to enlarged gauges GA, GB or GC shall only be allowed on lines widened to these gauges. The lines concerned are listed in the Infrastructure Register. All GA, GB and GC movements on lines not shown on this list shall be treated as special consignments.

Wagons and coaches built to gauges GA, GB or GC shall be identified by a marking as specified in Annex B 32

## C.4.1 STATIC GAUGE REFERENCE PROFILES AND ASSOCIATED RULES

The reference profiles for the static gauges GA GB and GC (see Fig. 20), together with their associated rules, apply exclusively to determining the maximum load profiles and on the condition that the coefficient of flexibility of the wagon + its load is not greater than that of the typical load considered, having the following characteristics:

$q+w=0{,}023m$; $p = 1{,}8m$; $d = 1{,}41m$;

$J = 0{,}005m$ $\eta_0 < 1°$ $h_C = 0{,}5m$

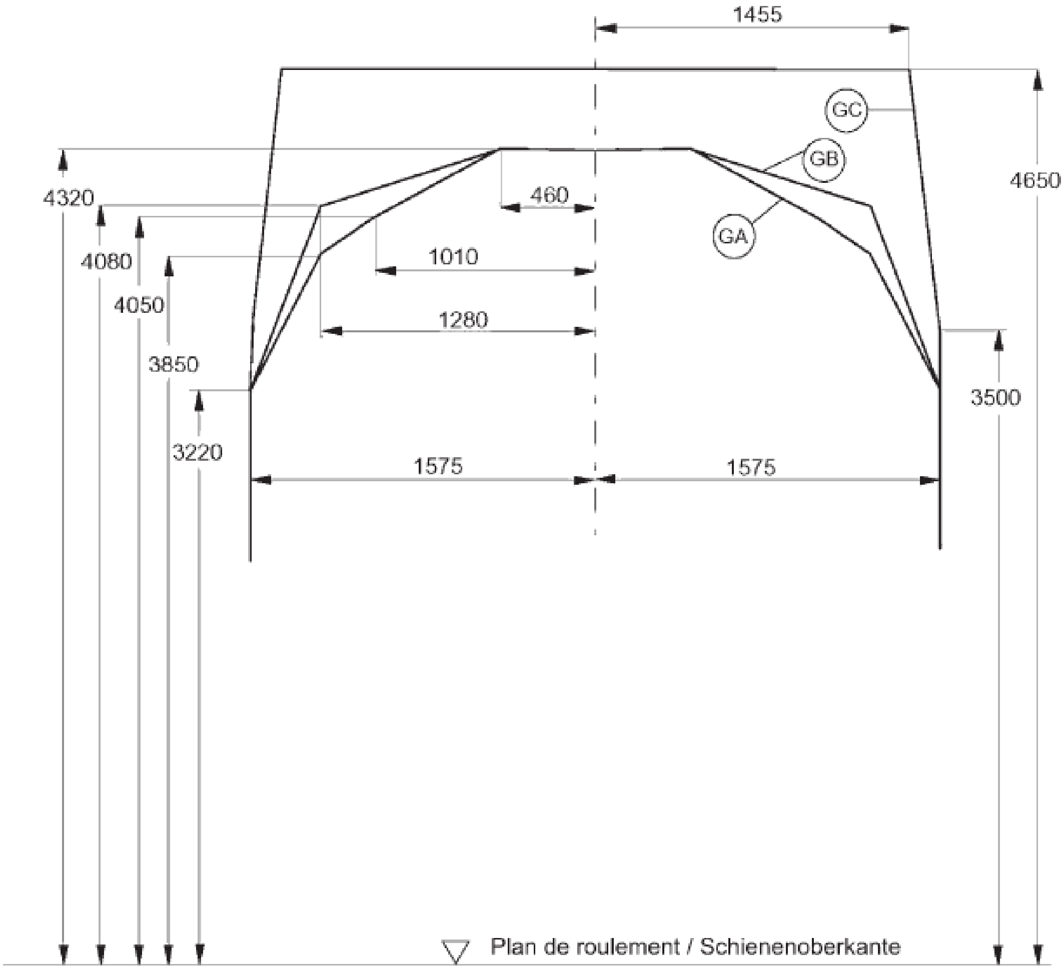
$s = 0{,}3$

vertical oscillations 0,03m (GA, GB); 0,05m (GC)

In view of tolerances on centring, the half-widths should be at most equal to those of the reference profiles reduced by the following values Ei and Ea.

REFERENCE PROFILES FOR STATIC GAUGES GA, GB and GC (load gauges)

*Fig. C20*




Note: Up to a height of 3 220 mm, the reference profile of the GA, GB and GC gauges is identical to that of the G1 gauge.

### C.4.1.1 GA and GB static gauges

– **Height h ≤ 3,22 m.** The $E_i$ and $E_a$ reduction formulae to be applied are those associated with the G1 static gauge.

– **Height h > 3,22 m.** The $E_i$ and $E_a$ reduction formulae to be applied are as follows:

a) For the sections between the bogie pivots or between the end axles of vehicles not mounted on bogies

When

$$\left(an - n^2 + \frac{p^2}{4}\right) \leq 7{,}5 + 32{,}5k \quad \Delta_i = 7{,}5 + 32{,}5k$$

When

$$\left(an - n^2 + \frac{p^2}{4}\right) > 7{,}5 + 32{,}5k \quad \Delta_i = an - n^2 + \frac{p^2}{4}$$

$$E_i = \left[\frac{\Delta_i}{500} + \frac{1{,}465 - d}{2} + q + w + x_{i>0} - 0{,}075 - 0{,}065k\right]_{>0} \qquad (601)$$

With

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right);$$

*k* = (see Table 1)

b) For sections beyond the bogie pivots or the end axles of vehicles not mounted on bogies

When

$$\left(an + n^2 - \frac{p^2}{4}\right) \leq 7{,}5 + 32{,}5k \ \Delta_a = 7{,}5 + 32{,}5k$$

When

$$\left(an + n^2 - \frac{p^2}{4}\right) > 7{,}5 + 32{,}5k \ \Delta_a = an + n^2 - \frac{p^2}{4}$$

$$E_a = \left[\frac{\Delta_a}{500} + \left(\frac{1{,}465 - d}{2} + q + w\right)\frac{2n + a}{a} + x_{a>0} - 0{,}075 - 0{,}065k\right]_{>0} \qquad (602)$$

With

$$x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - 100\right);$$

*k* = (see Table 1)

TABLE 1:

GA GAUGE

If

$$3{,}22<h<3{,}85 \text{ m}, \ k = \frac{h - 3{,}22}{0{,}63}$$

if

$$h \geq 3{,}85 \text{ m}, \ k = 1$$

GB GAUGE

if

$$3{,}22<h<4{,}08 \text{ m}, \ k = \frac{h - 3{,}22}{0{,}86}$$

If

$$h \geq 4{,}08 \text{ m}, \ k = 1$$

### C.4.1.2 GC static gauge

The $E_i$ and $E_a$ reduction formulae to be applied are those associated with the G1 static gauge irrespective of the value of h.

## C.4.2 KINEMATIC GAUGE REFERENCE PROFILES AND ASSOCIATED RULES

The GA, GB and GC kinematic gauge reference profiles (see Fig. 21) taken with their associated rules allow to determine the maximum construction profile for vehicles in the same way as when using the G1 gauge.

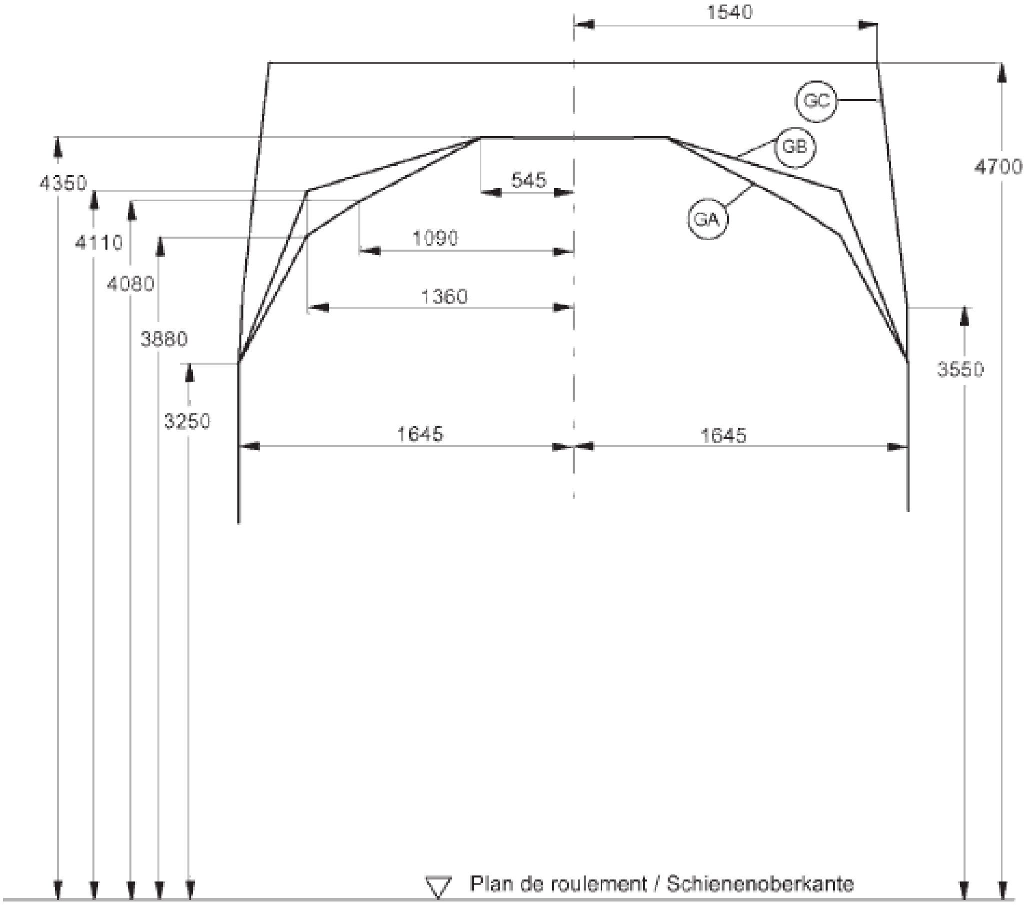
The rules for the kinematic calculations may be applied to clearly defined loads.

The term 'clearly defined loads' shall be understood to mean: transferable unit loads of known geometry, e.g. containers and swap bodies conveyed on carrier wagons fitted with load positioning devices, and semi-trailers with deflated air suspension or mechanical suspension with a known roll flexibility coefficient and conveyed on recess wagons.

Under these conditions the combination of a wagon and its load can be treated as a normal single wagon.

Reference profiles for GA, GB and GC kinematic gauges

*Fig. C21*




Note: Up to a height of 3 220 mm, the reference profile of the GA, GB and GC gauges is identical to that of the G1 gauge.

### C.4.2.1 Tractive units (except railcars and multiple unit motor coaches)

#### C.4.2.1.1 GA and GB kinematic gauges

- **Height h ≤ 3,25m.** The formulae to be applied are those associated with the G1 profile.
- **Height h > 3,25m.** The formulae to be applied are those associated with the G1 profile, with the exception of the formulae given under cases a) and b) below.

a) Vehicles for which the play w is independent of the track position radius or varies linearly with the track curvature

1) For sections **between** the bogie pivots or between the end axles of vehicles not mounted on bogies

When

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) \leq 7{,}5 + 32{,}5k$$

$$E_i = \frac{1{,}465 - d}{2} + q + w_\infty + z - 0{,}015 \qquad (603)$$

when

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) > 7{,}5 + 32{,}5k$$

$$E_i = \frac{an - n^2 + \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2} + q + w_{i(250)} + x_{i>0} - 0{,}030 - 0{,}065k \qquad (604)$$

with

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right) + w_{i(150)} - w_{i(250)}$$

*k* and z= (see table 2)

2) For sections **beyond** the bogie pivots or the end axles of vehicles not mounted on bogies

When

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(w_\infty - w_{i(250)}\right)\frac{n}{a} + \left(w_\infty - w_{i(250)}\right)\frac{n+a}{a}\right] \leq 7{,}5 + 32{,}5k$$

$$E_a = \left(\frac{1{,}465 - d}{2} + q + W_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \qquad (605)$$

When

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(W_\infty - W_{i(250)}\right)\frac{n}{a} + \left(W_\infty - W_{i(250)}\right)\frac{n+a}{a}\right] > 7{,}5 + 32{,}5k$$

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n + a}{a} + w_{i(250)}\frac{n}{a} + W_{a(250)}\frac{n+a}{a} + z + x_{a>0} - 0{,}030 - 0{,}065k \qquad (606)$$

With

$$x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - (120 - 20k)\right) + \left(W_{i(150)} - W_{i(250)}\right)\frac{n}{a} + \left(W_{a(150)} - W_{a(250)}\right)\frac{n+a}{a}$$

*k* and z= (see table 2)

b) Vehicles for which the play w varies non-linearly with the track curvature

1) For sections **between** the bogie pivots or the end axles of vehicles not mounted on bogies

For each point of the vehicle, the value of Ei to be taken is the greatest obtained from application of:

- formula (603) above
- formulae (607) and (608) below in which the value of R to be taken maximises the portion between the square brackets

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - (7{,}5 + 32{,}5k)}{2R} + w_{i(R)}\right] + \frac{1{,}465 - d}{2} + q + z - 0{,}015 \qquad (607)$$

with

$\infty > R \geq 250$ m

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 100}{2R} + w_{i(R)}\right] + \frac{1{,}465 - d}{2} + q + z - 0{,}170 - 0{,}065k \quad (608)$$

with 250 > R ≥ 150 m

*k* and z= (see table 2)

2) For sections **beyond** the bogie pivots or the end axles of vehicles not mounted on bogies

For each point on the vehicle, the value of Ea to be taken is the greatest obtained from application of:

– formula (605) above

formulae (609) and (610) below in which the value of R to be taken maximises the portion between the square brackets

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - (7{,}5 + 32{,}5k)}{2R} + w_{i(R)}\frac{n}{a} + W_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z - 0{,}015 \quad (609)$$

With

$\infty > R \geq 250$ m

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - (120 - 20k)}{2R} + w_{i(R)}\frac{n}{a} + W_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z - 0{,}210 - 0{,}105k \quad (610)$$

with 250 > R ≥ 150 m

*k* and z= (see table 2)

TABLE 2:

GA GAUGE

If

$3{,}25 < h < 3{,}38,\ k = \frac{h - 3{,}25}{0{,}63}$

If

$h \geq 3{,}88$ m, $k = 1$

GB GAUGE

if

$3{,}25 < h < 4{,}11,\ k = \frac{h - 3{,}25}{0{,}86}$

If

$h \geq 4{,}11$ m, $k = 1$

$$z = \left[\frac{s}{30} + \tan(\eta_0 - 1^\circ)_{>0}\right](h - h_c) + \left[\frac{s}{10}(h - h_c) - (0{,}04 - 0{,}01k)(h - 0{,}5)\right]_{>0}$$

### C.4.2.1.2 GC kinematic gauge

The formulae to be applied are those associated with the G1 profile, irrespective of the value of h.

### C.4.2.2 Railcars and multiple unit motor coaches

**Note :**

The gauge characteristics of railcars and multiple unit motor coaches whose bogies can be considered to be motor or trailer bogies are described in § 3.4.2.

### C.4.2.2.1 GA and GB kinematic gauges

- **Height h ≤ 3,25m.** The formulae to be applied are those associated with the G1 profile.
- **Height h > 3,25m.** The formulae to be applied are those associated with the G1 profile with the exception of the following formulae:
- Railcars and MU motor coaches with all bogies considered as powered: the formula are those given in § 3.4.1 (Traction units)
- Railcars and MU motor coaches considered to have only trailer bogies: the formulae are those given in § 3.4.3 (Passenger coaches and luggage vans)
- Railcars with a motor bogie and a trailer bogie: the reduction formulae given in 3.4.1 may either be applied as they stand, or replaced by the following formulae which offer manufacturers slight advantages in the centre-part and at the ends of the vehicle body.

a) Between the pivots ($_1$)[5]

$$E_i = \frac{1{,}465 - d}{2} + q + w_\infty \frac{a - n_\mu}{a} + w'_\infty \frac{n_\mu}{a} + z - 0{,}015 \tag{603a}$$

$$E_i = \frac{an_\mu + n_\mu^2 + \frac{p^2}{4}.\frac{a-n_\mu}{a} + \frac{p'^2}{4}.\frac{n_\mu}{a}}{500} + \frac{1{,}465 - d}{2}.\frac{a - n_\mu}{a} + q + w_{i(250)}\frac{a-n_\mu}{a} + w'_{i(250)}\frac{n_\mu}{a} + \tag{604a}$$

$$z + x_{i>0} - 0{,}015 - 0{,}015\frac{a-n_\mu}{a} - 0{,}065k$$

with

$$x_i = \frac{1}{750}\left(an_\mu - n_\mu^2 + \frac{p^2}{4}.\frac{a-n_\mu}{a} + \frac{p'^2}{4}.\frac{n_\mu}{a} - 100\right) + \left(w_{i(150)} - w_{i(250)}\right)\frac{a-n_\mu}{a} + \left(w'_{i(250)} - W'_{i(150)}\right)\frac{n_\mu}{a}$$

*k* and z= (see table 2)

b) Beyond the pivots on the motor bogie side ($_1$)

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \tag{605b}$$

$$E_a = \frac{an + n^2 - \frac{p^2}{4}.\frac{n+a}{a} + \frac{p'^2}{4}.\frac{n}{a}}{500} + \frac{1{,}465 - d}{2}.\frac{n+a}{a} + q\frac{2n+a}{a} + w'_{i(250)}\frac{n}{a} + w'_{a(250)}\frac{n+a}{a} + \tag{606b}$$

$$z + x_{i>0} - 0{,}030 - 0{,}065k$$

With

$$x_a = \frac{1}{750}\left(an + n^2 + \frac{p^2}{4}.\frac{n}{a} - \frac{p'^2}{4}.\frac{n+a}{a} - (120 - 20k)\right) + \left(w_{i(150)} - w_{i(250)}\right)\frac{n}{a} + \left(w'_{a(150)} - W'_{a(250)}\right)\frac{n+a}{a}$$

*k* and z= (see Table 2)

**Notes**

[5] The reduction to be applied for the same value of n is the greatest obtained with formula (603a) and (604a)

(1) This value applies to those parts no more than 0,400 m above the running surface and those which may descend below this level as a result of wear and vertical movements.

### C.4.2.2.2 GC kinematic gauge

The formulae to be applied are those associated with the G1 profile, irrespective of the value of h.

### C.4.2.3 Passenger coaches and luggage vans

### C.4.2.3.1 GA and GB kinematic gauges

- **Height h ≤ 3,25m.** The formulae to be applied are those associated with the G1 profile.
- **Height h > 3,25m.** The formulae to be applied are those associated with the G1 profile, with the exception of the formulae given under cases a) and b) below.

a) Vehicles for which the play w is independent of the track position radius or varies linearly with the track curvature

1) For sections **between** the bogie pivots

When

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) \leq 250(1{,}465 - d) + 32{,}5k$$

$$E_i = \left(\frac{1{,}465 - d}{2} + q + w + z - 0{,}015\right) \tag{611}$$

When

$$an - n^2 + \frac{p^2}{4} - 500\left(w_\infty - w_{i(250)}\right) > 250(1{,}465 - d) + 32{,}5k$$

$$E_i = \frac{an - n^2 + \frac{p^2}{4}}{500} + q + w_{i(250)} + z + x_{i>0} - 0{,}015 - 0{,}065k \tag{612}$$

With

$$x_a = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right) + w_{i(150)} - w_{i(250)}$$

*k* and z= (see table 3)

2) For sections **beyond** the bogie pivots

when

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(w_\infty - w_{i(250)}\right)\frac{n}{a} + \left(w_\infty - w_{i(250)}\right)\frac{n+a}{a}\right] \leq 250(1{,}465 - d)\frac{n}{a} + (7{,}5 + 32{,}5k)$$

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \tag{613}$$

When

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(w_\infty - w_{i(250)}\right)\frac{n}{a} + \left(w_\infty - w_{a(250)}\right)\frac{n+a}{a}\right] > 250(1{,}465 - d)\frac{n}{a} + (7{,}5 + 32{,}5k)$$

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2}\frac{n + a}{a} + q\frac{2n + a}{a} + w_{i(250)}\frac{n}{a} + w_{a(250)}\frac{n + a}{a} + z + x_{a>0} - 0{,}030 - 0{,}065k \tag{614}$$

With

$$x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - (120 - 20k)\right) + \left(w_{i(150)} - w_{i(250)}\right)\frac{n}{a} + \left(w_{a(150)} - W_{a(250)}\right)\frac{n+a}{a}$$

*k* and z= (see table 3)

b) Vehicles for which the play w varies non-linearly with the track curvature

1) For sections **between** the bogie pivots

For each point on the vehicle, the value of Ei to be taken is the greatest obtained from application of:

- formula (611) above
- formulae (615) and (616) below in which the value of R to be taken maximises the portion between the square brackets

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - (7,5 + 32,5k)}{2R} + w_{i(R)}\right] + q + z \qquad (615)$$

With
$\infty > R \geq 250$ m

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 100}{2R} + w_{i(R)}\right] + q + z + 0{,}185 - 0{,}065k \qquad (616)$$

with 250 > R ≥ 150 m

*k* and z = (see table 3)

2) For sections **beyond** the bogie pivots

For each point on the vehicle, the value of Ea to be taken is the greatest obtained from application of:

- formula (613) above
- formulae (617) and (618) below in which the value of R to be taken maximises the portion between the square brackets

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - (7,5 - 32,5k)}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \frac{1{,}465 - d}{2}\cdot\frac{n+a}{a} + q\cdot\frac{2n+a}{a} + z - 0{,}015 \qquad (617)$$

With
$\infty > R \geq 250$ m

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - (120 - 20k)}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \frac{1{,}465 - d}{2}\cdot\frac{n+a}{a} + q\cdot\frac{2n+a}{a} + z - 0{,}120 - 0{,}105k \qquad (618$$

with 250 > R ≥ 150 m

*k* and z= (see Table 3)

TABLE 3:

GA GAUGE

If

$$3{,}25<h<3{,}88\ \text{m},\ k=\frac{h-3{,}25}{0{,}63}$$

if h ≥ 3,88 m, k = 1

GB GAUGE

if

$$3{,}25<h<4{,}11\ \text{m},\ k=\frac{h-3{,}25}{0{,}86}$$

if h ≥ 4,11 m, k = 1

$$z=\left[\frac{s}{30}+\tan(\eta_0-1°)_{>0}\right](h-h_c)+\left[\frac{s}{10}(h-h_c)-(0{,}04-0{,}01k)(h-0{,}5)\right]_{>0}$$

### C.4.2.3.2 GC kinematic gauge

The formulae to be applied are those associated with the G1 profile, irrespective of the value of h.

### C.4.2.4 Wagons

### C.4.2.4.1 GA and GB kinematic gauges

- **Height h ≤ 3,25m.** The formulae to be applied are those associated with the G1 profile.
- **Height h > 3,25m.** The formulae to be applied are those associated with the G1 profile, with the exception of the formulae given under cases a) and b) below.

a) Vehicles not mounted on bogies

For sections **between** end axles

When

$an - n^2 \leq 7{,}5 + 32{,}5\ k$

$$E_i=\frac{1{,}465-d}{2}+q+w_\infty+z-0{,}015 \qquad (619)$$

When

$an - n^2 \leq 7{,}5 + 32{,}5\ k$

$$E_i=\frac{an-n^2}{500}+\frac{1{,}465-d}{2}+q+w+z-0{,}030-0{,}065k \qquad (620)$$

with *k* and z = (see Table 4)

For sections **beyond** the end axles

When

$an + n^2 \leq 7{,}5 + 32{,}5\ k$

$$E_a=\left(\frac{1{,}465-d}{2}+q+w\right)\frac{2n+a}{a}+z-0{,}015 \qquad (621)$$

When

$an + n^2 > 7{,}5 + 32{,}5\ k$

$$E_i=\frac{an-n^2}{500}+\left(\frac{1{,}465-d}{2}+q+w\right)\frac{2n+a}{a}+z-0{,}030-0{,}065k \qquad (622)$$

with *k* and z = (see Table 4)

b) Bogie vehicles

For sections **between** the bogie pivots

When

$$an - n^2 + \frac{p^2}{4} \leq 250(1{,}465 - d) + 32{,}5k$$

$$E_i = \frac{1{,}465 - d}{2} + q + w + z - 0{,}015 \qquad (623)$$

When

$$an - n^2 + \frac{p^2}{4} > 250(1{,}465 - d) + 32{,}5k$$

$$E_i = \frac{an + n^2 - \frac{p^2}{4}}{500} + q + w_{i(250)} + z + x_{i>0} - 0{,}015 - 0{,}065k \qquad (624)$$

with

$$x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 100\right) + w_{i(150)} - w_{i(250)}$$

*k* and z = (see Table 4)

For sections **beyond** the bogie pivots

When

$$an + n^2 - \frac{p^2}{4} \leq 250(1{,}465 - d)\frac{n}{a} + (7{,}5 + 32{,}5k)$$

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \qquad (625)$$

when

$$an + n^2 - \frac{p^2}{4} > 250(1{,}465 - d)\frac{n}{a} + (7{,}5 + 32{,}5k)$$

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2}\cdot\frac{n + a}{a} + (q + w)\frac{2n + a}{a} + z + x_{a>0} - 0{,}030 - 0{,}065k \qquad (614)$$

With

$$x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - (120 - 20k)\right)$$

*k* and z= (see table 4)

TABLE 4:

GA GAUGE

If

$$3{,}25 < h < 3{,}88 \text{ m},\ k = \frac{h - 3{,}25}{0{,}63}$$

if h≥3,88 m,k=1

GB GAUGE

If

$$3{,}25 < h < 4{,}11 \text{ m } k = \frac{h - 3{,}25}{0{,}86}$$

if h≥4,11 m, k=1

$$z = \left[\frac{s}{30} + \tan\left(\eta_0 + \arctan\frac{(J - 0{,}005) > 0}{b_G}\right)(1+s) - 1^\circ\right]_{>0}(h - h_c)^{>0} + \left[\frac{s}{10}(h - h_c) - (0{,}04 - 0{,}01k)(h - 0{,}05)\right]_{>0}$$

#### C.4.2.4.2 GC kinematic gauge

The formulae to be applied are those associated with the G1 profile, irrespective of the value of h.

## C.5 GAUGES REQUIRING BI- OR MULTILATERAL AGREEMENTS

The Infrastructure Managers of the different countries are free to conclude bi- or multilateral agreements between themselves in order to permit the running over the whole or part of their respective lines, of vehicles other than those built to the G1, GA, GB or GC profiles.

In order for such agreements to be made, it is sufficient to define a kinematic reference profile and associated rules.

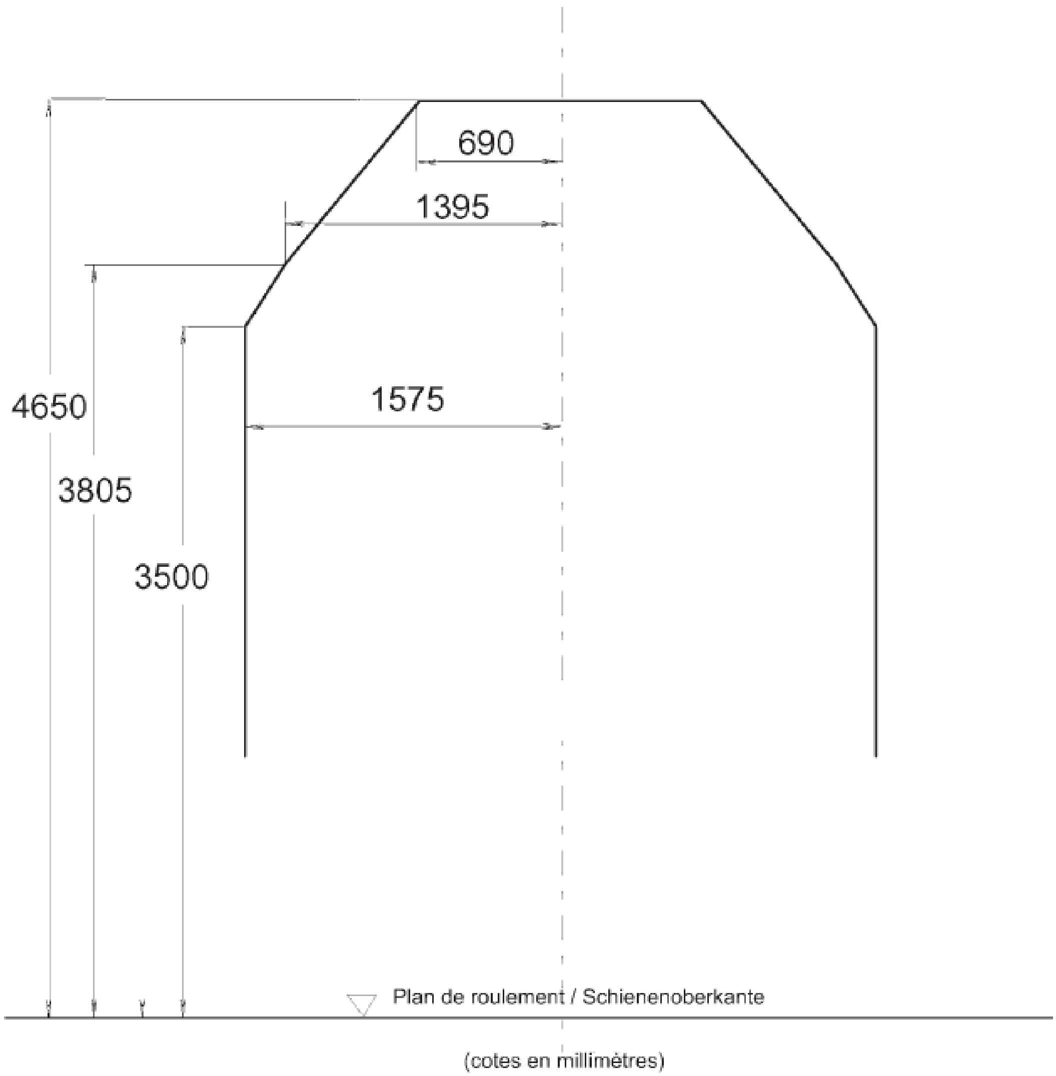
### C.5.1 G2 GAUGE

#### C.5.1.1 Reference profile of G2 static gauge

Certain Railways [6] authorise trains to run on their lines with loads fitting the reference profile shown below, for which the rules defined for static gauge G1 apply.

[6] Permitted by: HSH, GySEV, BHEV, PKP, BDZ, CFR, CD, ZSR, MAV, JZ, CH, TCDD, DB, ÖBB, CFL, NS, DSB, CFS, BV and IRR, except in the following stations:
JZ: Divaca, Sezana, Hrpelje-Kozina, Koper, Kilovce, Ilirska, Bistrica, Sapljane, Jurdani, Opatija-Matulji, Rijeka,
MAV: Budapest-Deli pu.-Budapest.Kelenföld

*Fig. C22*



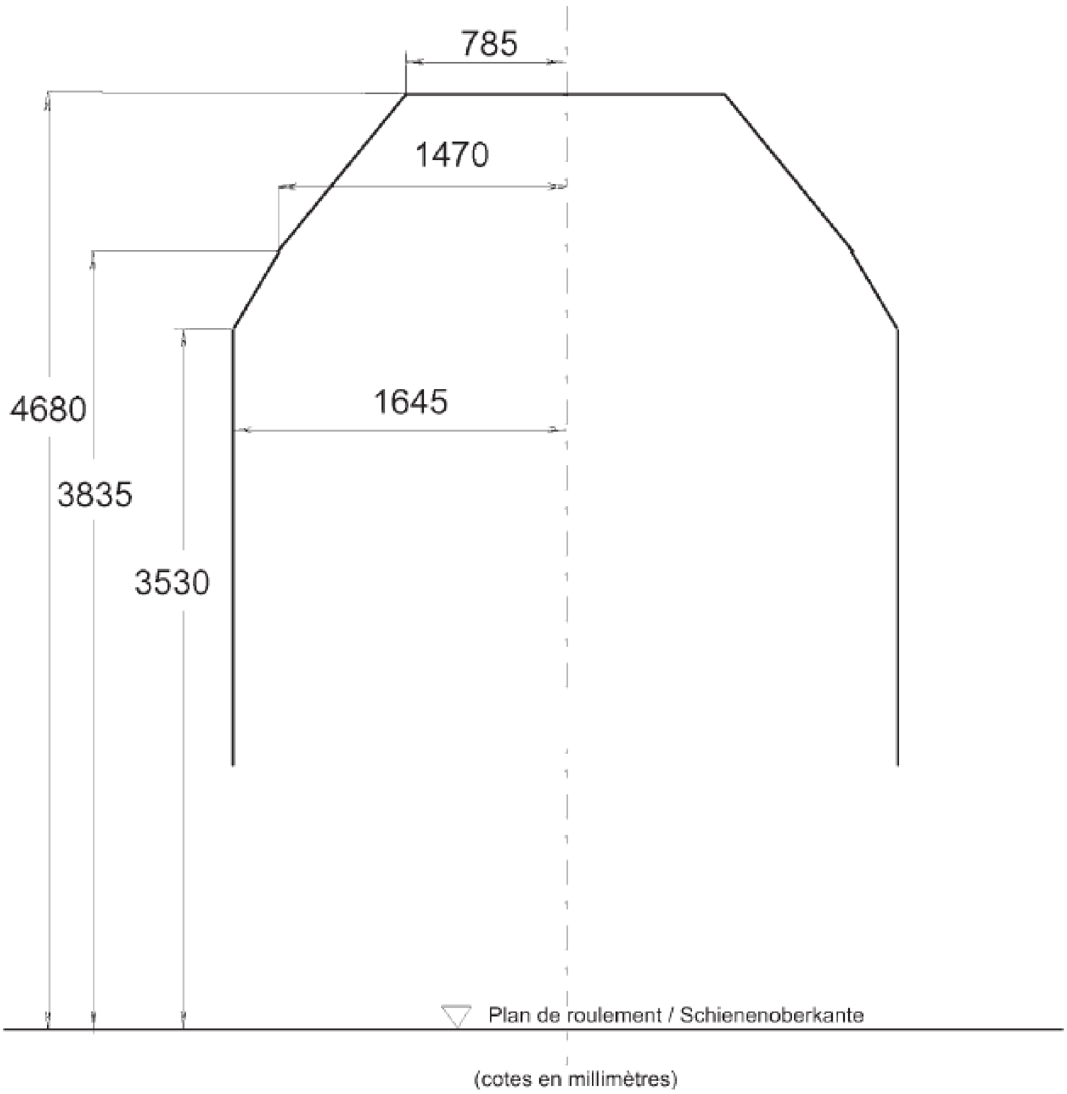

The Rules for the G1 static gauge should be applied.

**C.5.1.2 Reference profile of G2 kinematic gauge**

The following kinematic reference profile shall be considered equivalent for the purpose of applying the standards pertaining to kinematic profiles.

*OTIF UTP* | *Corresponding text in EU regulations* [1] | *EU ref.* [2]

*Fig. C23*




## C.5.2 GB1 AND GB2 GAUGES

### C.5.2.1 General

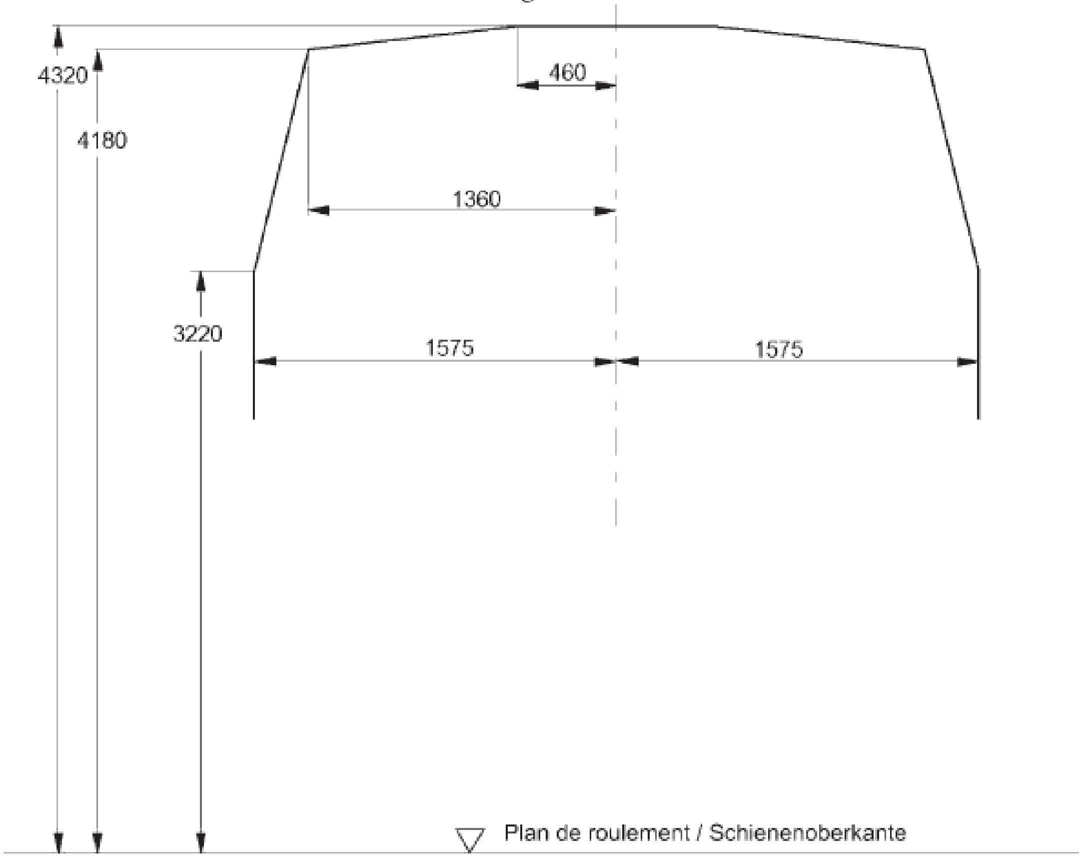
Gauges GB1 and GB2 were produced on the basis of certain combined transport requirements that emerged beginning in 1989.

Use of gauges GB1 and GB2 is subject to bi- or multilateral agreements being made between Infrastructure Managers.

### C.5.2.2 GB1 and GB2 static reference profiles (loading gauges)

GB1 static reference profile

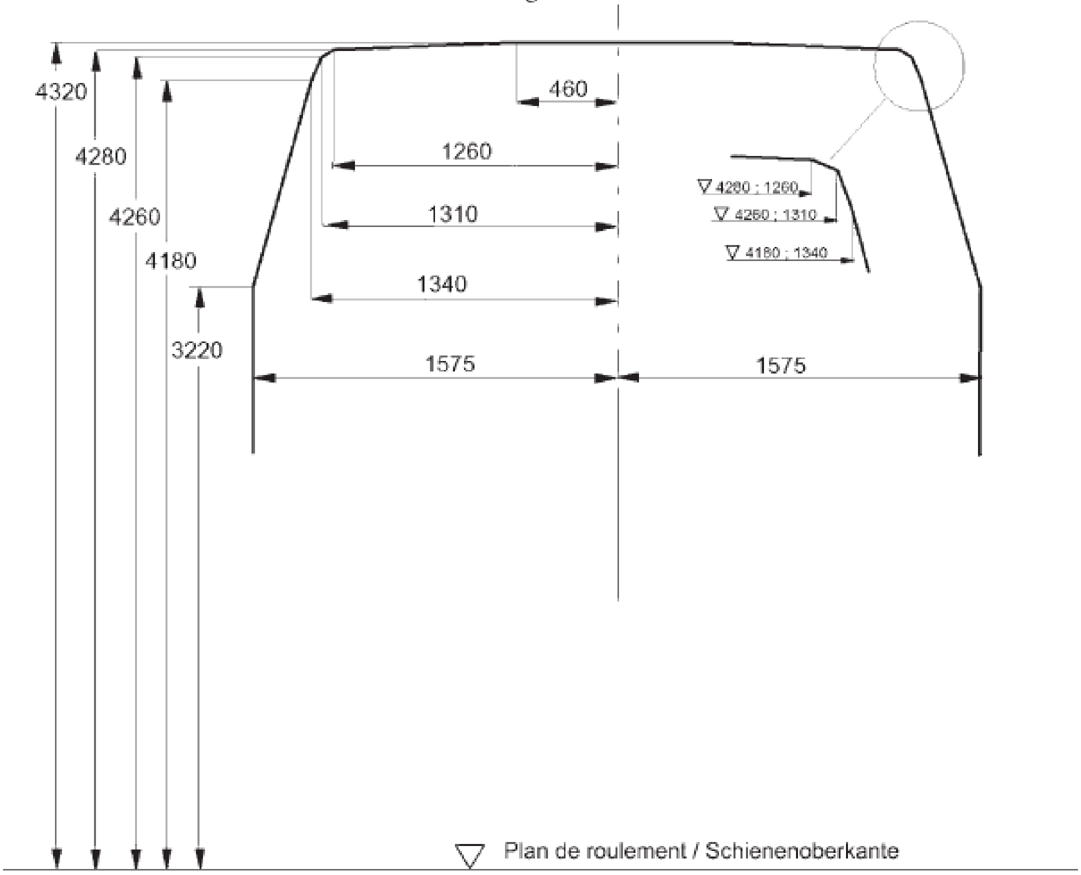
*Fig. C24*




**Note:**

Up to a height of 3 220 mm, the reference profile of the GB1 gauge is identical to that of the G1 gauge. GB2 static reference profile

Fig. C25




**Note:**

Up to a height of 3 220 mm, the reference profile of the GB2 gauge is identical to that of the G1 gauge.

### C.5.2.3 Rules for GB1 and GB2 static reference profiles

The rules to be applied are those for the GB gauge, except for the coefficient k given in Table 1, the value of which is to be applied is given in the table below:

GB1 and GB2 GAUGE

If

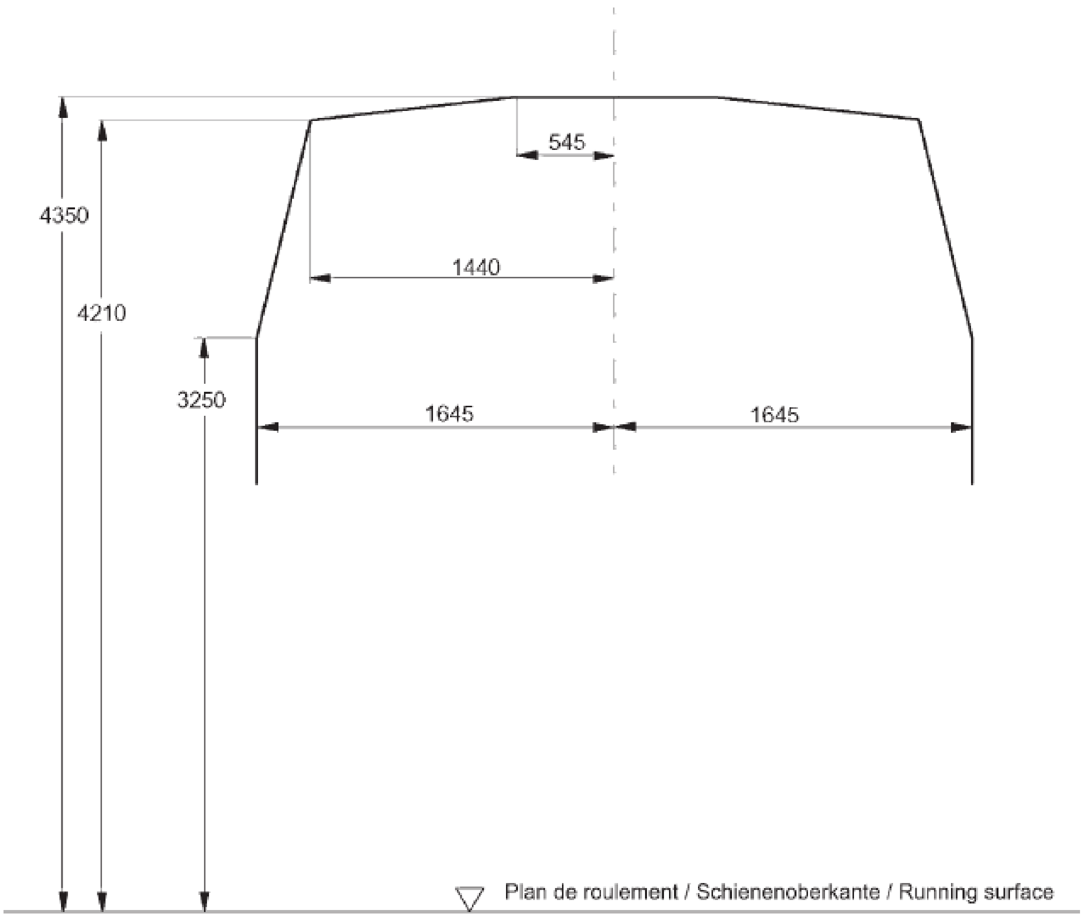
$$3{,}22<h<4{,}18\ \text{m},\ k=\frac{h-3{,}22}{0{,}96}$$

if h ≥ 4,18 m, k = 1

### C.5.2.4 GB1 and GB2 kinematic reference profiles

GB1 kinematic reference profile

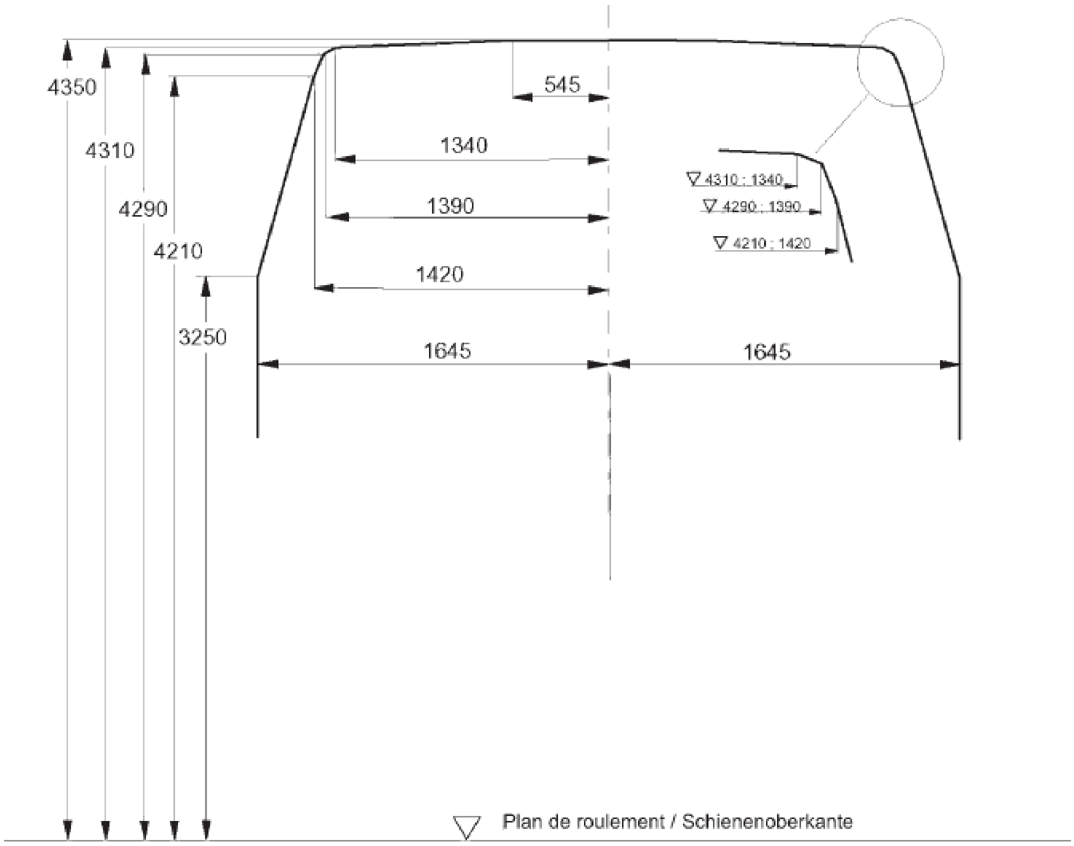
*Fig. C26*




**Note:**

Up to a height of 3 220 mm, the reference profile of the GB1 gauge is identical to that of the G1 gauge. GB2 kinematic reference profile

*Fig. C27*




**Note:**

Up to a height of 3 220 mm, the reference profile of the GB2 gauge is identical to that of the G1 gauge.

### C.5.2.5 Rules for GB1 and GB2 kinematic reference profiles

The rules applicable are those for the GB gauge, except for the coefficient k given in Tables 2, 3 and 4, the value of which is to be applied is given in the table below:

GB1 and GB2 GAUGE

If

$$3{,}25<h<4{,}21 \text{ m}, \ k = \frac{h-3{,}25}{0{,}96}$$

if h ≥ 4,21 m, k = 1

## C.5.3 GAUGE 3.3

### C.5.3.1 General

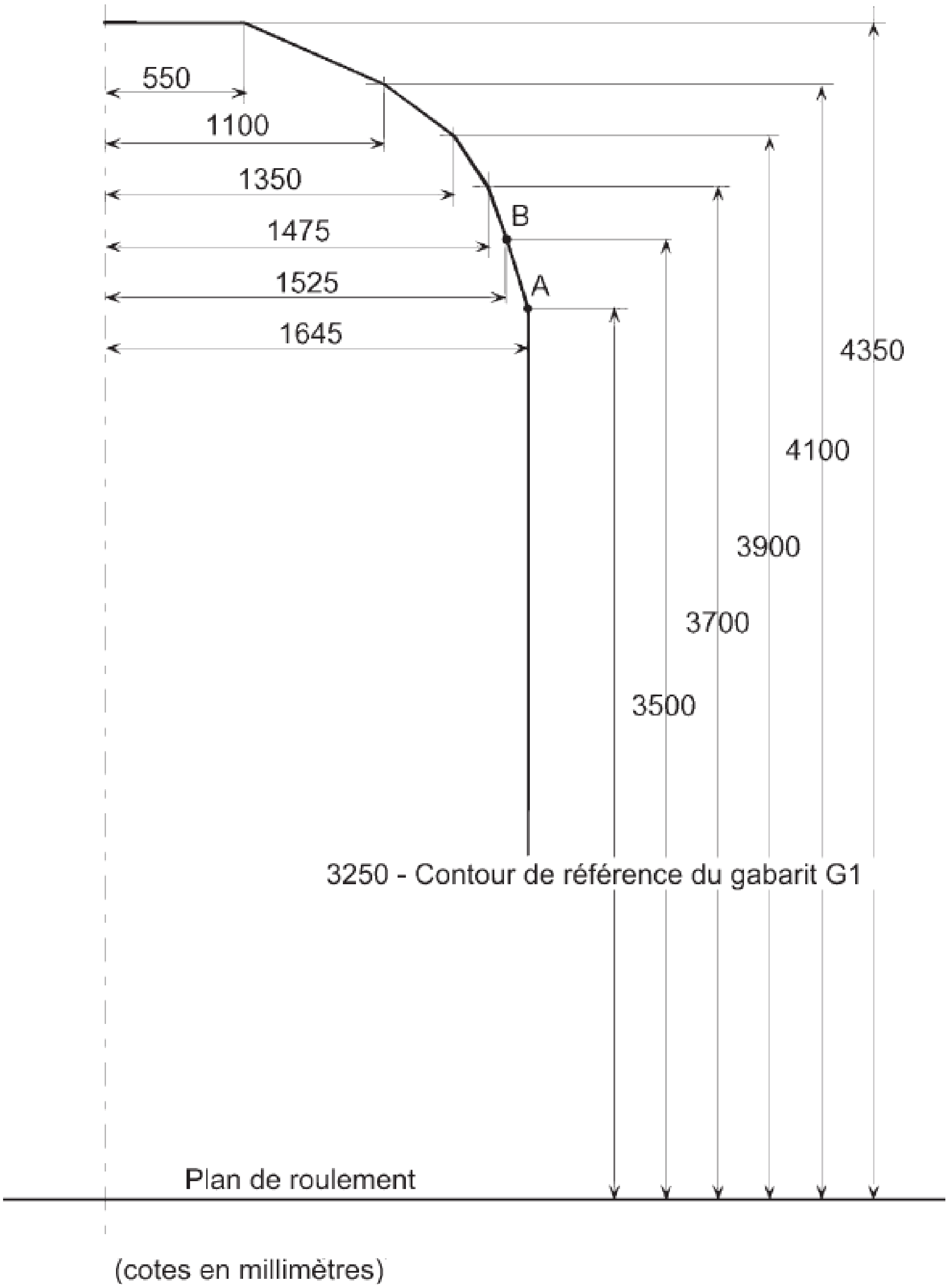
Kinematic gauge 3.3 can be used for services running on the French network (Réseau Ferré National — RFN).

This gauge affords additional space towards the top compared with the G1 gauge. It is applicable to vehicles (for example, double-decker coaches) that run only on lines with gauge 3.3 clearances.

Gauge 3.3 concerns only the top part of the reference profile, above 3,25 m, the bottom part being common to the G1 gauge. As any other gauge, it is associated with a reference profile and associated rules.

**C.5.3.2 Reference profile of 3.3 kinematic gauge**

Fig. C28




**C.5.3.3 Rules for the reference profile to determine the maximum construction gauge**

The rules for the reference profile of the 3.3 gauge are identical to those for the G1 gauge, except for the following specific details:

– Permitted projections $S_o$ (S)

– Quasi-static displacements z.

**C.5.3.3.1 Permitted projections $S_o$ (S)**

For the parts located higher than 3,500 m from the running surface, the value $S_o$ of the projection to be taken into account as a function of the curve to calculate the reductions $E_i$ and $E_a$ is $\frac{37,5}{R}$ irrespective of the type of vehicle.

– Thus, the effective projections S must not exceed the following $S_o$ values:
  - 0,15 m on 250 m radius curves
  - 0,15 m on 150 m radius curves.

Moreover, on straight (tangent) track, $S_o$ is set equal to 0,015 m.

– For the parts located higher than 3,250 m lower than 3,500 m above the running surface, that is the parts between levels A and B of the reference profile, there are no rules for fixing the value of $S_o$ of the maximum projection. The determination the maximum construction gauge between these two levels is done by joining the point of the maximum construction gauge corresponding to Level A, found by calculating the reductions from the projections according to the rules for the G1 gauge, to the point of the maximum construction gauge corresponding to Level B, found by calculating the reductions from the above-stated projections.

– For the parts located less than 3,250 m above the running surface, the general rule for the G1 gauge should be applied.

**C.5.3.3.2 Quasi-static displacements z**

For suspended components, located at a height h, the value of z is given by the formula:

$$Z = \left[\frac{S}{30} + \tan\left[\eta_0 - 1^\circ\right]_{>0}\right] \lvert h - h_C \rvert + \left[\frac{S}{10} \lvert h - h_C \rvert - 0{,}03 \left[h - 0{,}5\right]_{>0}\right]_{>0}$$

**C.5.3.4 Reduction formulae**

Reduction formulae applicable to:

| | |
|---|---|
| – tractive vehicles (locomotives, power cars) | paragraph C.5.3.4.1 |
| – multiple units | paragraph C.5.3.4.2 |
| – coaches | paragraph C.5.3.4.3 |

**C.5.3.4.1 Reduction formulae applicable to tractive units (dimensions in metres)**

Tractive units for which the play w is independent of the track position radius or varies linearly with the track curvature

Internal reductions Ei (where $n = n_i$)

Sections between the end axles of traction vehicles not mounted on bogies or between the bogie pivots.

When

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) \le 67{,}5$$

, the position on straight track is preponderant:

$$Ei = \frac{1{,}465 - d}{2} + q + W_\infty + z - 0{,}015 \qquad (101$$

When

$$an - n^2 + \frac{p^2}{4} - 500\left(W_\infty - W_{i(250)}\right) > 67{,}5$$

, the position on curved track is preponderant:

$$E_i = \frac{an - n^2 + \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2} + q + _{i(250)} + Z + [x_i]_{>0} - 0{,}150 \qquad (102)$$

$$\text{with } x_i = \frac{1}{750}\left(an - n^2 + \frac{p^2}{4} - 75\right) + W_{i(150)} - W_{i(250)} \qquad (103)$$

External reductions Ea (where n = na)

Sections beyond the end axles of vehicles not mounted on bogies or the bogie pivots of bogied tractive vehicles.

When

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(W_\infty - W_{i(250)}\right)\frac{n}{a} + \left(W_\infty - W_{a(250)}\right)\frac{n+a}{a}\right] \leq 67{,}5$$

, the position on straight track is preponderant:

$$E_a = \left(\frac{1{,}465 - d}{2} + q + W_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \qquad (106)$$

When

$$an + n_2 - \frac{p^2}{4} - 500\left[\left(W_\infty - W_{i(250)}\right)\frac{n}{a} + \left(W_\infty - W_{a(250)}\right)\frac{n+a}{a}\right] > 67{,}5,$$

the position on curved track is preponderant:

$$E_a = \frac{an + n_2 - \frac{p^2}{4}}{500} + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n + a}{a} + W_{i(250)}\frac{n}{a} + W_{a(250)}\frac{n+a}{a} + z + [x_a]_{>0} - 0{,}150 \qquad (107)$$

$$\text{mit } x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - 75\right) + \left(W_{i(150)} - W_{i(250)}\right)\frac{n}{a} + \left(W_{a(150)} - W_{a(250)}\right)\frac{n+a}{a} \qquad (108)$$

Tractive vehicles for which the play w varies non-linearly with the track curvature (exceptional case)

For each section of the tractive vehicle, the reduction to be taken is the greatest of those resulting from the application of the above-given formulae, in which the value of R to be used is that which gives the highest value for the part between square brackets, and the formula (101) or (106).

Internal reductions Ei (with n = ni)

When

$\infty > R \geq 250$

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 67{,}5}{2R} + w_{i(R)}\right] + \frac{1{,}465 - d}{2} + q + z - 0{,}015 \qquad (104)$$

When 250 > R ≥ 150

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 75}{2R} + w_{i(R)}\right] + \frac{1{,}465 - d}{2} + q + z \qquad (105)$$

In practice, formulae (105) and (110) have no effect, since the variation in play w, resulting from the variable stops taking effect, begins only when R>250 m.

When

$\infty > R \geq 250$

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - 67{,}5}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z - 0{,}015$$

When 250> R ≥ 150

$$E_a = \left[\frac{an + n^2 + \frac{p^2}{4} - 75}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z$$

External reductions Ea (where n = na)

When

$\infty > R \geq 250$

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - 67{,}5}{2R} + w_{i(R)}\frac{n}{a} + w_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z - 0{,}015 \qquad (109)$$

When 250> R ≥ 150

$$E_a = \left[\frac{an + n^2 + \frac{p^2}{4} - 75}{2R} + W^{i(R)}\frac{n}{a} + W_{a(R)}\frac{n+a}{a}\right] + \left(\frac{1{,}465 - d}{2} + q\right)\frac{2n+a}{a} + z \qquad (110)$$

**C.5.3.4.2 Reduction formulae applicable to multiple units (dimensions in metres) ***

For multiple units having a motor bogie and a trailer bogie (see the table for Gauge G1):

**Internal reductions Ei$_{(1)}$**

Sections **between** bogie pivots

$$E_i = \frac{1{,}465 - d}{2} + q + W_\infty\frac{a - n_\mu}{a} + W'_\infty\frac{n_\mu}{a} + z - 0{,}015 \qquad (101a)$$

$$E_i = \frac{an_\mu - n_\mu^2 + \frac{p^2}{4}\cdot\frac{a-n_\mu}{a} + \frac{p'^2}{4}\cdot\frac{n_\mu}{a}}{500} + \frac{1{,}465 - d}{2}\cdot\frac{a-n_\mu}{a} + q + W_{i(250)}\frac{a-n_\mu}{a} + W'_{i(250)}\frac{n_\mu}{a} + z + [x_i]_{>0} - 0{,}150 \qquad (102a)$$

With

$$x_i = \frac{1}{750}\left[an_\mu - n_\mu^2 + \frac{p^2}{4}\cdot\frac{a-n_\mu}{a} + \frac{p'^2}{4}\cdot\frac{n_\mu}{a} - 75\right] + \left(W_{i(150)} - W_{i(250)}\right)\frac{a-n_\mu}{a} + \left(W'_{i(150)} - W'_{i(250)}\right)\frac{n_\mu}{a} \qquad (103a)$$

**External reductions Ea$_{(2)}$ motor bogie end** (at the front in the running direction)

Sections **beyond** the bogie pivots (where n = na)

$$E_a = \left[\frac{1{,}465 - d}{2} + q\right]\frac{2n+a}{a} + W_\infty\frac{n+a}{a} + W'_\infty\frac{n}{a} + z - 0{,}015 \qquad (106a)$$

$$E_a = \frac{an + n^2 - \frac{p^2}{4}\cdot\frac{n+a}{a} + \frac{p'^2}{4}\cdot\frac{n}{a}}{500} + \frac{1{,}465 - d}{2}\cdot\frac{n+a}{a} + q\frac{2n+a}{a} + W'_{i(250)}\frac{n}{a} + W_{a(250)}\frac{n+a}{a} + z + [x_a]_{>0} - 0{,}150 \qquad (107a)$$

With

$$x_a = \frac{1}{750}\left[an + n^2 - \frac{p^2}{4}\cdot\frac{n+a}{a} + \frac{p'^2}{4}\cdot\frac{n}{a} - 75\right] + \left(W'_{i(150)} - W'_{i(250)}\right)\frac{n}{a} + \left(W_{a(150)} - W_{a(250)}\right)\frac{n+a}{a} \qquad (108a)$$

(1), (2) The reduction to apply for a given value of n is the greatest one resulting from the formulae:

- (101 a) or (102 a) and (103 a);
- (106 a) or (107 a) and (108 a).

**External reductions Ea$_{(1)}$ trailer bogie end** (at the front in the running direction)

Sections **beyond** the bogie pivots (where n = na)

$$E_a = \left[\frac{1{,}465-d}{2}+q\right]\frac{2n+a}{a}+w_\infty\frac{n}{a}+w'_\infty\frac{n+a}{a}+z-0{,}015 \qquad (106b)$$

$$E_a = \frac{an+n^2+\frac{p^2}{4}\frac{n}{a}-\frac{p'^2}{4}\frac{n+a}{a}}{500}+\left(\frac{1{,}465-d}{2}+q\right)\frac{2n+a}{a}+w_{i(250)}\frac{n}{a}+w'_{a(250)}\frac{n+a}{a}+z+ \qquad (107b)$$
$$[x_a]_{>0}-0{,}150$$

$$x_a = \frac{1}{750}\left[an+n^2+\frac{p^2}{4}\frac{n}{a}-\frac{p'^2}{4}\frac{n+a}{a}-75\right]+\left(w_{i(150)}-w_{i(250)}\right)\frac{n}{a}+\left(w'_{a(150)}-w'_{a(250)}\right)\frac{n+a}{a} \qquad (108b)$$

(1) The reduction to apply for a given value of n is the greatest one resulting from the formulae:

(106 b) or (107 b) and (108 b).

### C.5.3.4.3 Reduction formulae applicable to coaches and other passenger vehicles (dimensions in metres)

For bogie coaches, except the bogies themselves and their associated parts.

*Coaches for which the play w is independent of the track position radius or varies linearly with the track curvature.*

**Internal reductions E$_i$**

Sections **between** bogie pivots (where n = ni)

When

$$an-n^2+\frac{p^2}{4}-500\left(w_\infty-w_{i(250)}\right)\le 250(1{,}465-d)+67{,}5$$

the position on straight track is preponderant:

$$E_a = \frac{1{,}465-d}{2}+q+w_\infty+z-0{,}015 \qquad (201)$$

When

$$an-n^2+\frac{p^2}{4}-500\left(w_\infty-w_{i(250)}\right) > 250(1{,}465-d)+67{,}5$$

the position on curved track is preponderant:

$$E_i = \frac{an-n^2+\frac{p^2}{4}}{500}+q+w_{i(250)}+z+[x_i]_{>0}-0{,}150 \qquad (202)$$

$$\text{with } x_i = \frac{1}{750}\left(an-n^2+\frac{p^2}{4}-75\right)+w_{i(150)}-w_{i(250)} \qquad (203)$$

External reductions Ea

Sections beyond bogie pivots (where n = na)

When

$$an+n^2-\frac{p^2}{4}-500\left[\left(w_\infty-w_{i(250)}\right)\frac{n}{a}+\left(w_\infty-w_{a(250)}\right)\frac{n+a}{a}\right]\le 250(1{,}465-d)\frac{n}{a}+67{,}5$$

the position on straight track is preponderant:

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n + a}{a} + z - 0{,}015 \qquad (206)$$

When

$$an + n^2 - \frac{p^2}{4} - 500\left[\left(w_\infty - w_{i(250)}\right)\frac{n}{a} + \left(w_\infty - w_{a(250)}\right)\frac{n + a}{a}\right] > 250(1{,}465 - d)\frac{n}{a} + 67{,}5$$

the position on curved track is preponderant:

$$E_a = \frac{an + n^2 - \frac{p^2}{4}}{500} + \frac{1{,}465 - d}{2}\cdot\frac{n + a}{a} + q\frac{2n + a}{a} + w_{i(250)}\frac{n}{a} + w_{a(250)}\frac{n + a}{a} + z + [x_a]_{>0} - 0{,}150 \qquad (207)$$

$$\text{with } x_a = \frac{1}{750}\left(an + n^2 - \frac{p^2}{4} - 75\right) + \left(w_{i(150)} - w_{i(250)}\right)\frac{n}{a} + \left(w_{a(150)} - w_{a(250)}\right)\frac{n + a}{a} \qquad (208)$$

Coaches for which the play w varies non-linearly with the track curvature.

For each section of the coach, the reduction to be taken is the greatest of those resulting from the application of the abovegiven formulae, in which the value of R to be used is that which gives the highest value for the part between square brackets, and the formula (201) or (206).

**Internal reductions Ei (where n = ni)**

When

$\infty > R \geq 150$

$$E_i = \left[\frac{an - n^2 + \frac{p^2}{4} - 75}{2R} + w_{i(R)}\right] + q + z \qquad (204)$$

External reductions Ea (where n = na)

when

$\infty > R \geq 250$

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - 67{,}5}{2R} + W_{i(R)}\frac{n}{a} + W_{a(R)}\frac{n + a}{a}\right] + \frac{1{,}465 - d}{2}\cdot\frac{n + a}{a} + q\frac{2n + a}{a} + z - 0{,}015$$

When 250 > R ≥ 150

$$E_a = \left[\frac{an + n^2 - \frac{p^2}{4} - 75}{2R} + W_{i(R)}\frac{n}{a} + W_{a(R)}\frac{n + a}{a}\right] + \frac{1{,}465 - d}{2}\cdot\frac{n + a}{a} + q\frac{2n + a}{a} + z$$

## C.5.4 GAUGE GB-M6

### C.5.4.1 General

The GB-M6 kinematic gauge can be used in services running on the Belgian (SNCB) network.

The GB-M6 kinematic gauge is based on the same principles as the G1 gauge, it is adapted to the SNCB infrastructure and its reduction formulae are likewise adapted as concerns the verification radii and the projections permitted in curves.

The permitted projections are more generous than those for the G1 gauge and therefore make it possible to run wider vehicles.

Concerning the pantograph, in addition to the UIC 505-1 regulations allowing vehicles equipped with 1 950 mm-wide pantographs to run, the SNCB infrastructure also accommodates 1 760 mm-wide pantographs fitted on more flexible vehicles with characteristics as follows: s ≤ 0,4 and (q + w) ≤ 0,065 m.

The bogies as well as their ancillary components fitted to vehicles built to this gauge strictly follow the rules for the G1 gauge.

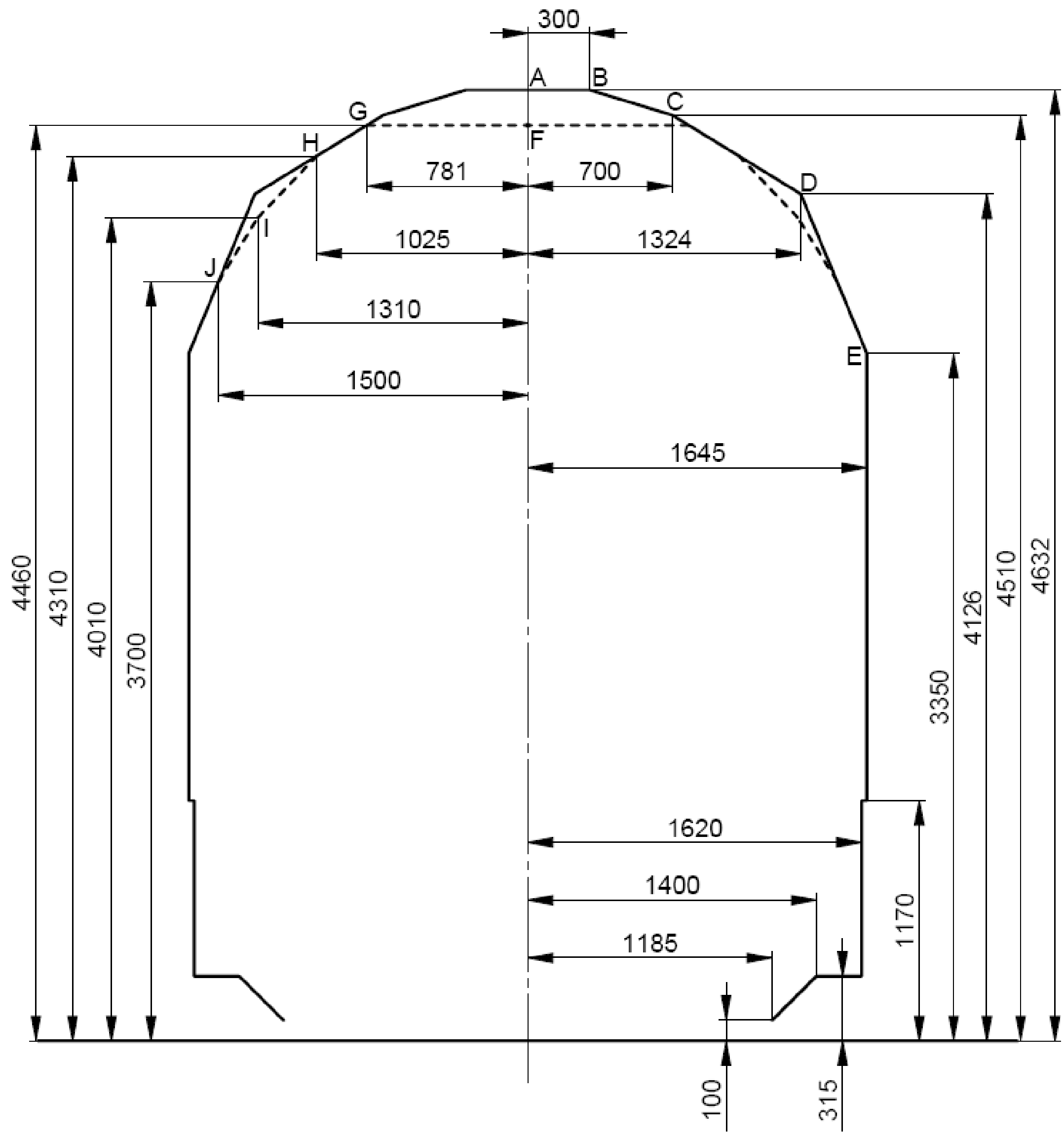
Suspended parts located at a level, or which might descend to a level, less than 100 mm above the running surface due to vertical displacements are calculated in accordance with the G1 rules.

When, due to vertical movements, a point located near the 1 170 mm level might rise above or drop below this level, it is necessary to consider the minimum permitted width, by using either the formulae governing the parts above 1 170 mm, or the formulae governing the parts below or at the 1 170 mm level.

The choice between the reduction formulae for tractive units or for hauled units is made in the same way as for the G1 gauge, based on the coefficient of adhesion at start-up.

### C.5.4.2 Reference profile of the GB-M6 kinematic gauge

Fig. C29



### C.5.4.3 Reduction formulae

#### C.5.4.3.1 Tractive vehicles

a) Reduction formulae for h > 1 170 mm.

Sections **between** bogie pivots

When

$$\frac{n(a-n)+\frac{p^2}{4}}{800}-\left(w_\infty - w_{i(400)}\right) \leq 0{,}015$$

$$E_i = \frac{1{,}465-d}{2}+q+w_\infty+z-0{,}015$$

When

$$\frac{n(a-n)+\frac{p^2}{4}}{800}-\left(w_\infty - w_{i(400)}\right) > 0{,}015$$

$$E_i = \frac{n(a-n)+\frac{p^2}{4}}{800}+w_{i(400)}+\frac{1{,}465-d}{2}+q+z+\left[x_i+(y_i)_{>0}\right]_{>0}-0{,}030$$

With

$$x_i = \frac{6}{10}\left[\frac{n(a-n)+\frac{p^2}{4}}{800}\right]-0{,}042-\left(w_{i(400)}-w_{i(250)}\right)$$

With

$$y_i = \frac{16}{15}\left[\frac{n(a-n)+\frac{p^2}{4}}{800}\right]-0{,}108-\left(w_{i(250)}-w_{i(150)}\right)$$

Sections **beyond** bogie pivots

When

$$\frac{n(a+n)-\frac{p^2}{4}}{800}-\left[\left(w_\infty - w_{i(400)}\right)\frac{n}{a}+\left(w_\infty - w_{a(400)}\right)\frac{n+a}{a}\right] \leq 0{,}015$$

$$E_a = \left(\frac{1{,}465-d}{2}+q+w_\infty\right)\frac{2n+a}{a}+z-0{,}015$$

When

$$\frac{n(a+n)-\frac{p^2}{4}}{800}-\left[\left(w_\infty - w_{i(400)}\right)\frac{n}{a}+\left(w_\infty - w_{a(400)}\right)\frac{n+a}{a}\right] > 0{,}015$$

$$E_a = \frac{n(a+n)-\frac{p^2}{4}}{800}+\left(q+w_{i(400)}\right)\frac{n}{a}+\left(q+w_{a(400)}\right)\frac{n+a}{a}+\left(\frac{1{,}465-d}{2}\right)\frac{2n+a}{a}+z+\left[x_a+(y_a)_{>0}\right]_{>0}-0{,}030$$

With

$$x_a = \frac{6}{10}\left[\frac{n(a+n)-\frac{p^2}{4}}{800}\right] - 0{,}042 - \left[\left(w_{i(400)} - w_{i(250)}\right)\frac{n}{a} + \left(w_{a(400)} - w_{a(250)}\right)\frac{n+a}{a}\right]$$

With

$$y_a = \frac{16}{15}\left[\frac{n(a+n)-\frac{p^2}{4}}{800}\right] - 0{,}108 - \left[\left(w_{i(250)} - w_{i(150)}\right)\frac{n}{a} + \left(w_{a(250)} - w_{a(150)}\right)\frac{n+a}{a}\right]$$

c) Reduction formulae for heights 100 < h ≤ 1 170 mm.

Sections **between** bogie pivots

When

$$\frac{n(a-n)+\frac{p^2}{4}}{2000} - \left(W_\infty - W_{i(1000)}\right) \leq 0{,}005$$

$$E_i = \frac{1{,}465-d}{2} + q + W_\infty + z - 0{,}015$$

When

$$\frac{n(a-n)+\frac{p^2}{4}}{2000} - \left(W_\infty - W_{i(1000)}\right) > 0{,}005$$

$$E_i = \frac{n(a-n)+\frac{p^2}{4}}{2000} + \frac{1{,}465-d}{2} + q + W_{i(1000)} + z + [x_i]_{>0} - 0{,}020$$

With

$$x_i = \frac{17}{3}\left[\frac{n(a-n)+\frac{p^2}{4}}{2000}\right] - 0{,}150 - \left(W_{i(1000)} - W_{i(150)}\right)$$

Sections **beyond** bogie pivots

When

$$\frac{n(a+n)-\frac{p^2}{4}}{2000} - \left[\left(W_\infty - W_{i(1000)}\right)\frac{n}{a} + \left(W_\infty - W_{a(1000)}\right)\frac{n+a}{a}\right] \leq 0{,}005$$

$$E_a = \left(\frac{1{,}465-d}{2} + q + W_\infty\right)\frac{2n+a}{a} + z - 0{,}015$$

When

$$\frac{n(a+n)-\frac{p^2}{4}}{2000} - \left[\left(W_\infty - W_{i(1000)}\right)\frac{n}{a} + \left(W_\infty - W_{a(1000)}\right)\frac{n+a}{a}\right] > 0{,}005$$

$$E_a = \frac{n(a+n)-\frac{p^2}{4}}{2000} + \left(\frac{1{,}465-d}{2}\right)\frac{2n+a}{a} + \left(q + W_{i(1000)}\right)\frac{n}{a} + \left(q + W_{a(1000)}\right)\frac{n+a}{a} + z + [x_a]_{>0} - 0{,}020$$

With

$$x_a = \frac{17}{3}\left[\frac{n(a+n)-\frac{p^2}{4}}{2000}\right] - 0{,}150 - \left[\left(W_{i(1000)} - W_{i(150)}\right)\frac{n}{a} + \left(W_{a(1000)} - W_{a(150)}\right)\frac{n+a}{a}\right]$$

### C.5.4.3.2 Hauled vehicles

a) Reduction formulae for height h >1 170 mm.

Sections **between** bogie pivots

When

$$\frac{n(a-n)+\frac{p^2}{4}}{800} - \left(w_\infty - w_{i(400)}\right) \leq \frac{1{,}465-d}{2}$$

$$E_i = \frac{1{,}465-d}{2} + q + w_\infty + z - 0{,}015$$

When

$$\frac{n(a-n)+\frac{p^2}{4}}{800} - \left(w_\infty - w_{i(400)}\right) > \frac{1{,}465-d}{2}$$

$$E_i = \frac{n(a-n)+\frac{p^2}{4}}{800} + q + w_{i(400)} + z + \left[x_i + \left(y_i\right)_{>0}\right]_{>0} - 0{,}015$$

With

$$x_i = \frac{6}{10}\left[\frac{n(a-n)+\frac{p^2}{4}}{800}\right] - 0{,}042 - \left(w_{i(400)} - w_{i(250)}\right)$$

With

$$y_i = \frac{16}{15}\left[\frac{n(a-n)+\frac{p^2}{4}}{800}\right] - 0{,}108 - \left(w_{i(250)} - w_{i(150)}\right)$$

Sections **beyond** bogie pivots

when

$$\frac{n(a+n)-\frac{p^2}{4}}{800} - \left[\left(w_\infty - w_{i(400)}\right)\frac{n}{a} + \left(w_\infty - w_{a(400)}\right)\frac{n+a}{a}\right] \leq \left(\frac{1{,}465-d}{2}\right)\frac{n}{a} + 0{,}015$$

$$E_a = \left(\frac{1{,}465-d}{2} + q + w_\infty\right)\frac{2n+a}{a} + z - 0{,}015$$

When

$$\frac{n(a+n)-\frac{p^2}{4}}{800} - \left[\left(w_\infty - w_{i(400)}\right)\frac{n}{a} + \left(w_\infty - w_{a(400)}\right)\frac{n+a}{a}\right] > \left(\frac{1{,}465-d}{2}\right)\frac{n}{a} + 0{,}015$$

$$E_a = \frac{n(a+n) - \frac{p^2}{4}}{800} + \left(q + w_{i(400)}\right)\frac{n}{a} + \left(q + w_{a(400)}\right)\frac{n+a}{a} + \left(\frac{1{,}465 - d}{2}\right)\frac{n+a}{a} + z + \left[x_a + (y_a)_{>0}\right]_{>0} - 0{,}030$$

With

$$x_a = \frac{6}{10}\left(\frac{n(a+n) - \frac{p^2}{4}}{800}\right) - 0{,}042 - \left[\left(w_{i(400)} - w_{i(250)}\right)\frac{n}{a} + \left(w_{a(400)} - w_{a(250)}\right)\frac{n+a}{a}\right]$$

With

$$y_a = \frac{16}{15}\left(\frac{n(a+n) - \frac{p^2}{4}}{800}\right) - 0{,}108 - \left[\left(w_{i(250)} - w_{i(150)}\right)\frac{n}{a} + \left(w_{a(250)} - w_{a(150)}\right)\frac{n+a}{a}\right]$$

b) Reduction formulae for heights 100 < h ≤1 170 mm.

Sections between bogie pivots

With

$$\frac{n(a-n) + \frac{p^2}{4}}{2000} - \left(w_\infty - w_{i(1000)}\right) \le \frac{1{,}465 - d}{2} - 0{,}010$$

$$E_i = \frac{1{,}465 - d}{2} + q + w_\infty + z - 0{,}015$$

When

$$\frac{n(a-n) + \frac{p^2}{4}}{2000} - \left(w_\infty - w_{i(1000)}\right) > \frac{1{,}465 - d}{2} - 0{,}010$$

$$E_i = \frac{n(a-n) + \frac{p^2}{4}}{2000} + q + w_{i(1000)} + z + [x_i]_{>0} - 0{,}005$$

With

$$x_i = \frac{17}{3}\left(\frac{n(a-n) + \frac{p^2}{4}}{2000}\right) - 0{,}150 - \left(w_{(1000)} - w_{i(150)}\right)$$

Sections **beyond** bogie pivots

When

$$\frac{n(a+n) - \frac{p^2}{4}}{2000} - \left[\left(w_\infty - w_{i(1000)}\right)\frac{n}{a} + \left(w_\infty - w_{a(1000)}\right)\frac{n+a}{a}\right] \le \left(\frac{1{,}465 - d}{2}\right)\frac{n}{a} + 0{,}005$$

$$E_a = \left(\frac{1{,}465 - d}{2} + q + w_\infty\right)\frac{2n+a}{a} + z - 0{,}015$$

When

$$\frac{n(a+n)-\frac{p^2}{4}}{2000}-\left[(W_\infty-W_{i(1000)})\frac{n}{a}+(W_\infty-W_{a(1000)})\frac{n+a}{a}\right]>\left(\frac{(1{,}465-d)}{2}\right)\frac{n}{a}+0{,}005$$

$$E_a=\frac{n(a+n)-\frac{p^2}{4}}{2000}+\left(\frac{1{,}465-d}{2}\right)\frac{n+a}{a}+(q+W_{i(1000)})\frac{n}{a}+(q+W_{a(1000)})\frac{n+a}{a}+z+[x_a]_{>0}-0{,}020$$

With

$$x_a=\frac{17}{3}\left(\frac{n(a+n)-\frac{p^2}{4}}{2000}\right)-0{,}050-\left[(W_{i(1000)}-W_{i(150)})\frac{n}{a}+(W_{a(1000)}-W_{a(150)})\frac{n+a}{a}\right]$$

# C.6 APPENDIX 1

## C.6.1 ROLLING STOCK LOADING GAUGE

### C.6.1.1 Conditions concerning doors, steps and footboards

1. Carriage doors

a) In opened position, carriage doors whose bottom-most part is at least 1 050 mm above the rail-top, when the vehicle is in the lowest permissible position for the buffers, may project beyond the vehicle's reduced clearance gauge by at most 200 mm.

On vehicles built after 1.1.1986, the carriage doors must meet this requirement even during door opening.

This requirement does not apply to hinged doors fitted to coaches prior to 1.1.1980.

b) At shunting speeds up to about 30 km/h, lateral play generally does not exceed 0,02 m.

For bodyside doors located beyond the bogie pivots and whose bottom edges are located less than 1 050 mm above the rail-top, the necessary reduction of the gauge, in the lowest permissible, 980 mm buffer position, can be reduced

- during opening and
- in opened position

by a maximum of

$$\frac{(w_a-0{,}02)(n+a)}{a}$$

This applies only if $w_a > 0{,}02$ m

It shall be permitted to use doors that meet the requirements of both a) and b) above. In that case, the requirements under a) must be met also during door opening.

2. Steps and footboards

When the bottom step is retractable, the necessary reduction of the loading gauge for running with the step down may be cut back at most by the value:

$$w_i\frac{n}{a}+w_a\frac{n+a}{a}$$

# C.7 APPENDIX 2

## C.7.1 ROLLING STOCK LOADING GAUGE

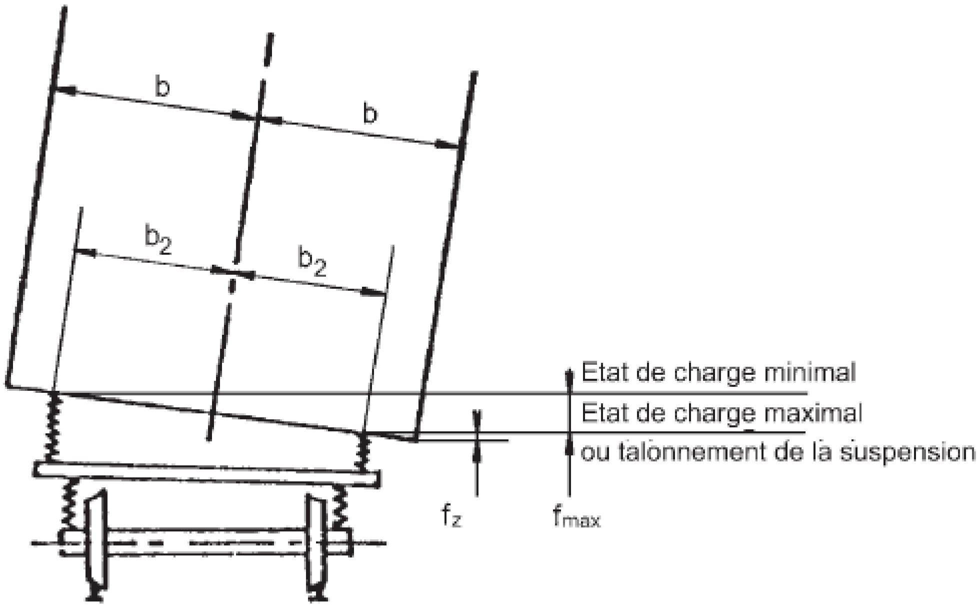
### C.7.1.1 Compression of the suspensions for areas outside the support polygon B, C and D

1. For all vehicles, and wagons in particular, it may be necessary to take account of additional vertical movements $f_z$ due to inclination of the vehicle body (roll, pitching) following, for example, an off-centre load or deflation of a pneumatic suspension.

The following simplified formulae can be used for these additional compressions:

– Lateral: zones concerned B and C

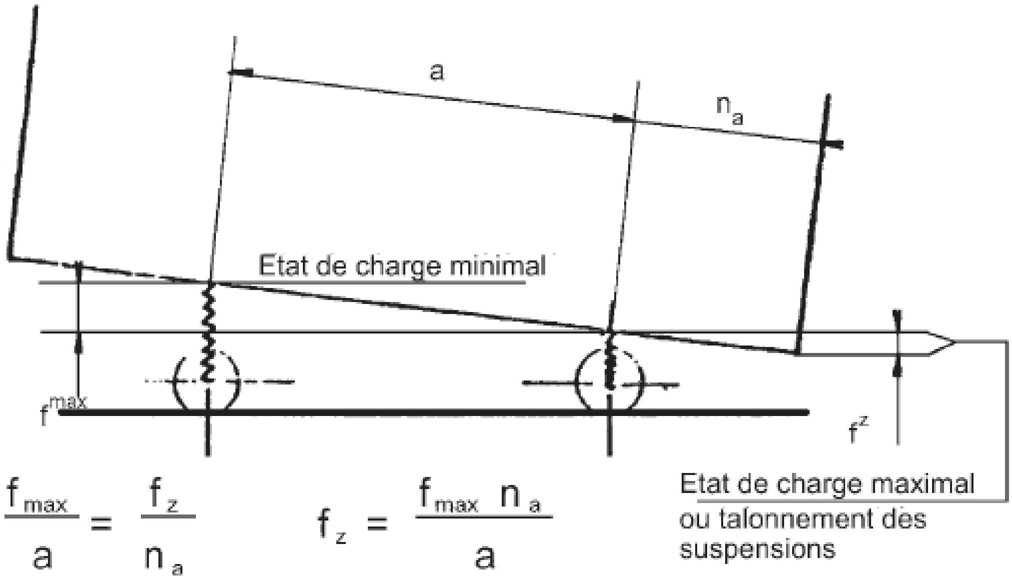
Compression in phase on 2 bogies and a single rail.




$$\frac{f_{max}}{2b_2} = \frac{f_z}{b - b_2} \qquad f_z = \frac{f_{max}(b - b_2)}{2b_2}$$

– Longitudinal: zones concerned, C and D

Compression on single bogie or axle.

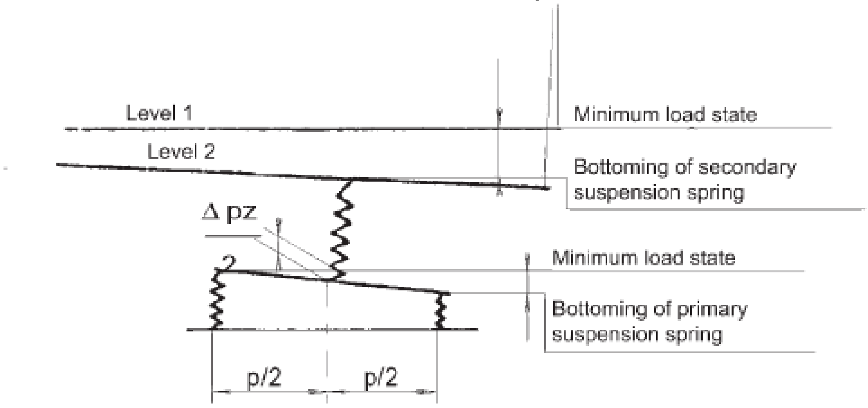



$$\frac{f_{max}}{a} = \frac{f_z}{n_a} \qquad f_z = \frac{f_{max}\ n_a}{a}$$

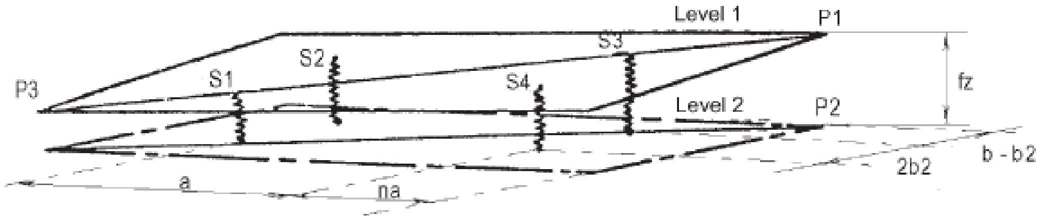
– Deflection of a primary suspension spring and a secondary suspension spring or deflated pneumatic suspension

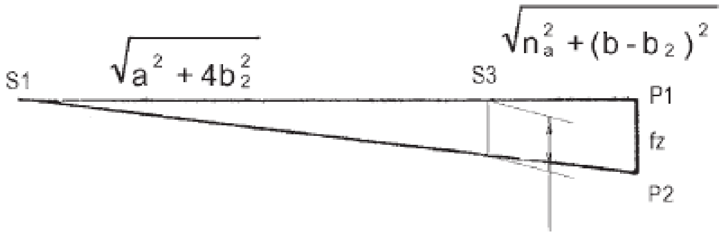
(calculation principle zone C).

Deflection (in an initial approach).




Approximate formula:




$$f_{max} = \Delta sz + \frac{\Delta pz}{2}$$

$$f_z = (\Delta sz + \Delta pz / 2)\ (1 + \frac{\sqrt{n_a^2 + (b - b_2)^2}}{\sqrt{a^2 + 4b_2^2}})$$

Legend :

Niveau 1: Level 1

Etat de charge minimal: Minimum load state

Talonnement du ressort de suspension primaire/secondaire: Bottoming of primary/secondary suspension spring

Formule approchée: Approximate formula

# C.8 APPENDIX 3 ROLLING STOCK LOADING GAUGE

## C.8.1 CALCULATION OF THE LOADING GAUGE OF TILTING VEHICLES

### C.8.1.1 General

The acceptance into international service of rolling stock fitted with tilting body systems shall be subject to bilateral or multilateral agreements between the railways concerned.

### C.8.1.2 Scope

This Appendix deals with the method of calculating the loading gauge of tilting body vehicles, hereinafter designated by the abbreviation **TBV**.

Paragraphs 2, 3 and 4 deal with the technical analysis of the calculation of the loading gauge of TBVs.

Paragraph 5 comments on the conditions of tilting and the speed of TBVs.

### C.8.1.3 Field of application

A TBV is defined as a vehicle in which the body can perform a rolling movement relative to the running gear when the vehicle goes round a curve, with the object of compensating for the centrifugal acceleration.

The appearance and the introduction into international service of trainsets made up of vehicles fitted with tilting body systems required certain modifications to be made to the rules regarding the loading gauge calculations for conventional vehicles.

This Appendix deals with the calculation rules for TBVs to obtain the maximum loading gauge for vehicle construction.

### C.8.1.4 Background

The TBV concept began to be developed in the years 1970-80 in several European countries in order to run with higher speeds on existing lines without detriment to the comfort of the passengers.

The speed in curves of railway vehicles is restricted because of the lateral acceleration which acts on the passengers: this limit of uncompensated acceleration is of the order of 1 to 1,3 $ms^{-2}$.

TBV units, in particular those fitted with active systems, can run with higher values of uncompensated acceleration (for example 1,82 $ms^{-2}$ for the FIAT ETR 450 train, equivalent to a cant deficiency of 278 mm) because the tilting of the body enables the values of the lateral acceleration felt by the passengers to be reduced.

### C.8.1.5 Conditions related to safety

The Builders of TBV units shall provide evidence that the vehicles meet the loading gauge under all the different cases of operation that are planned.

In addition to the calculation of the loading gauge, the Builder shall supply a report on the criteria adopted and on the devices on which safety depends, that is devices that must 'fail safe'.

Failure cases which might result in TBV units exceeding the reference profile shall be investigated by the Builder. Depending on the seriousness of their effects, special measures shall be taken by the Railways, that may concern railway operations, alarms, warnings to the driver, etc.

The Builder shall also guarantee that the tilting system is so designed that the units cannot run with values of uncompensated acceleration higher than the values allowed for conventional vehicles if the tilting system fails.

### C.8.1.6 Symbols used

The following additional symbols are used in this Appendix:

IP = value of the cant deficiency considered for the TBV

IC = value of the maximum cant deficiency permitted by the Permanent Way Department of the Railway ($_1$) [7]

E = value of the cant

zP = quasi-static displacements determined according to the needs of the TBV units

[7] The justification of the need to take account of this parameter, fixed by the Permanent Way Department of the Railways, in the rolling stock dimensional calculations is given in Section 3.2.2 of this Appendix.

## C.8.2 BASIC CONDITIONS TO DETERMINE THE LOADING GAUGE OF TBV UNITS

For the calculation of the loading gauge of TBV units, all the running conditions shall be examined both with the tilting system active and inactive.

The worst cases shall be examined, in particular:

SITUATION 1) case of a vehicle running in a curve with maximum cant deficiency (maximum body tilt);

SITUATION 2) case of a vehicle stationary in a curve. When an active TBV is stopped on a curve its position does not differ from that of a conventional vehicle and, therefore, can be dealt with using the principles and formulae applicable to a conventional vehicle.

Note also that for certain types of passive TBV units, such as the TALGO, there is no quasi-static inclination z due to the flexibility, i.e. s = 0.

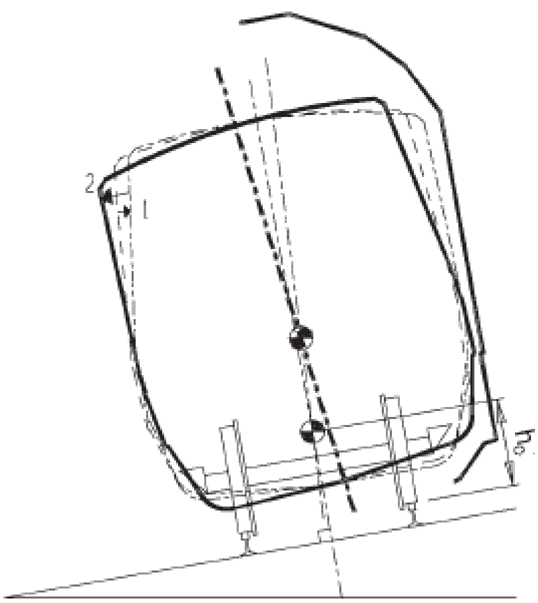
### C.8.2.1 Types of body tilting systems

In spite of the above, the different tilting system designs can be grouped according to the method of tilt of the bodies. This tilt can be obtained either with a natural or an equivalent tilting movement (passive tilt) when the centre of rotation of the body is above the position of the bodies' centre of gravity, as in the TALGO system, or by jacks which tilt the body depending on the radius of curvature and the speed (by an active tilting movement as in the FIAT system).

Let us examine the inclination of the body allowed by the different body tilting systems:

In the case of TBVs fitted with **ACTIVE systems**, the bodies are subjected to a quasi-static tilt caused by the uncompensated acceleration: This is not, however, the same as the body tilt imparted separately by the system. **Figure 1a** shows the principle of the inclination of a vehicle with an active tilt system.

*Fig. C30*

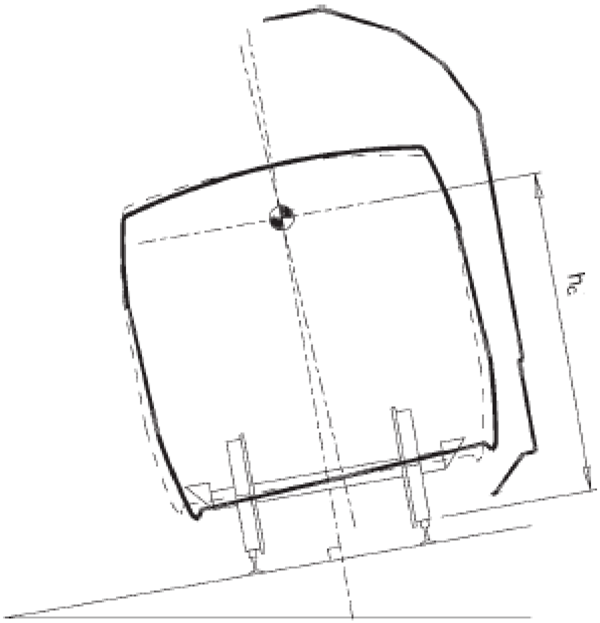



The actual movements can be broken down into a rotation due to the roll (movement 1) and a rotation superimposed on that by the active system (movement 2).

In the case of **PASSIVE systems** the body tilts naturally under the effect of the centrifugal force applied, which is proportional to the cant deficiency.

Figure **1b** shows the principle of inclination of a vehicle with natural or passive tilt.

Fig. C31




## C.8.3 ANALYSIS OF THE FORMULAE

### C.8.3.1 Basic formulae

Depending on the different types of TBV to be investigated (coaches, power cars or multiple unit motor coaches) the corresponding formulae for the G1 gauge shall be used, to which shall be added all the modifications presented in this Appendix.

### C.8.3.2 Modifications to be made to the formulae for TBVs

For TBVs the maximum tilt of the body corresponding to the maximum cant deficiency IP must be considered. Given this requirement, the following terms of the reduction formulae shall have to be reconsidered:

a) Lateral plays: (1,465-d)/2, q and w ($_1$) [8]

The sign of the lateral displacements, in general, should take account of the centrifugal effect.

The changes required are discussed in § 8.3.2.1.

b) Quasi-static displacements ‘z’

The term z is valid provided that vehicles do not exceed, when running, the cant deficiency value IP = 200 mm.

As TBVs can exceed this value and, in general, because of the fact that they can run with values of cant deficiency IP greater than those specified by the Permanent Way Department (IC), the formula needs some modifications which are discussed in § 8.3.2.2.

c) For certain types of TBV, especially the active ones, a further term to take account of the body tilt imparted by the system will need to be added to the formulae for calculating the reductions (see 8.3.2.3).

[8] For the TBV calculation this term must be measured at the height hc above the running surface of the rail. It can have different values for a same given vehicle, depending on configuration, according to the tilt technology and possible re-centring of the body.

**C.8.3.2.1 Expression for the values of the lateral plays when the body is tilted**

The condition of maximum body tilt occurs only when the vehicle runs round a curve with the maximum value of IP.

As the vehicle is submitted to a very high centrifugal force towards the outside of the curve, the terms of the lateral displacements shall be reconsidered.

- The play w shall be taken towards the outside of the curve.
- For the plays (1,465 - d)/2 and q it is necessary to distinguish between bogie vehicles and vehicles with independent wheels.

Bogie vehicles, calculation of play on the inside of the curve:

On-line tests have shown that for bogie vehicles, some axles run round the curve with the flange in contact with the outer rail, while others do not maintain this contact constantly. As a result and for safety reasons, the plays mentioned above shall be taken equal to zero.

Bogie vehicles, calculation of play on the outer side of the curve:

The plays (1,465 - d)/2 and q shall be taken, likewise for reasons of safety, on the outside of the curve.

Vehicles with independent wheels:

The tests have confirmed that the plays (1,465 - d)/2 and q occur towards the outside of the curve.

**C.8.3.2.2 Quasi-static displacement of a TBV**

To obtain the clearances to structures, the Permanent Way Department must add certain terms to the dimension of the reference profile. The quasi-static displacements of vehicles are calculated with the formula below:

$$\frac{0,4}{1,5}\left[E_{ou} I - 0,05\right]_{>0} \cdot (h - 0,5)_{>0}$$

The maximum allowable value for E $_{or}$ I is 200 mm.

Each Infrastructure Manager fixes for its lines its own maximum value for I. The values generally used are between 90 and 180 mm.

Vehicles must not exceed this maximum value of I when running.

On the other hand, TBVs reach higher values. This means that their dimensions need to be checked with a different calculation for the quasi-static displacements.

Just as for conventional vehicles, the effect of a cant deficiency induces in TBV units a tilting of the body around a longitudinal axis, a rotation which is due to the flexibility of the suspension system. In the formulae, the quasi-static displacements corresponding to this rotation are taken into consideration in the term ‘z’. Because TBVs can run with cant deficiencies of up to $I_p$ it is necessary to revise the calculation of this term (zP).

It is appropriate to introduce this new term zP, the formulation of which takes account of the total quasi-static tilt due to IP, in relation to that considered by the Permanent Way Department, IC (see paragraphs 3.2.2.1 and 3.2.2.2).

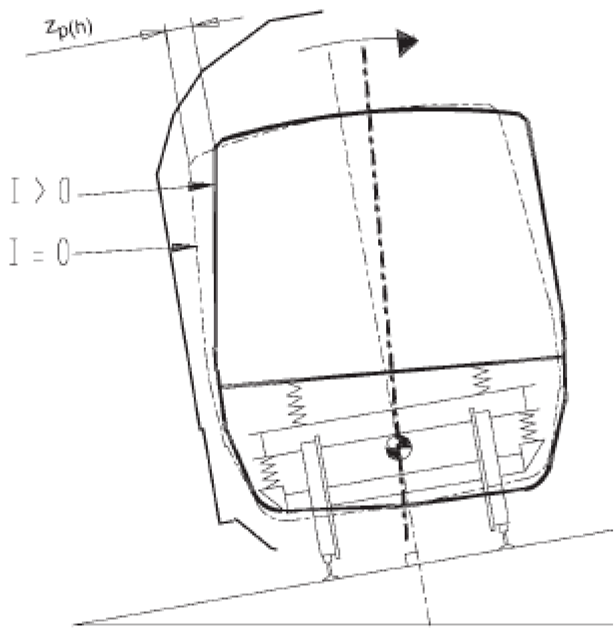
Moreover, for the active tilting systems, it is necessary to consider a supplementary term (see 3.2.3), because the tilting of the body to compensate for the centrifugal acceleration is independent of the tilt due to the roll.

**C.8.3.2.2.1 Expression of the quasi-static displacements zP for the reductions on the inside of the curve**

Under the effect of the lateral acceleration associated with IP values greater than 0, the body of the vehicle, because of the flexibility of the suspensions, tilts towards the outside of the curve when active tilting is used and towards the inside of the curve when passive tilting is used. The following figures show this type of displacement from the position I = 0. Due to the different modes of tilting, with the active system the displacements are largest at the upper part of the vehicle body, whereas with the passive system they are largest at the lower part of the vehicle body.

*Fig. C32:*

**ACTIVE system**




**Note:**

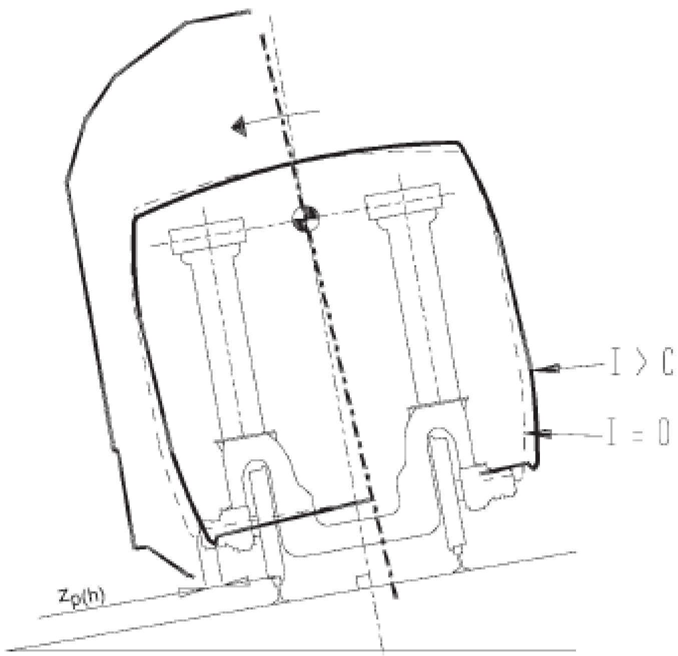
The tilt imparted by the system is not represented here.

– Since the reference profile is considered from the standpoint of the inside of the curve, the points of the vehicle situated at a height h>hc move away from the profile. The value of this displacement in the calculation will carry a minus sign.

The opposite is true for points situated at a height h < hc.

Fig. C33:

PASSIVE system




– Since the reference profile is considered from the standpoint of the inside of the curve, the points of the vehicle situated at a height h<hc move away from the profile. The value of this displacement in the calculation will have a minus sign.
– The opposite is true for points situated at a height of h > hc.

The displacements corresponding to different tilts shown in Figures 2a and 2b are indicated below.

**For a TBV unit with an active system** running on a curve with a cant deficiency IP the quasi-static displacements are:

$$Z_P = \frac{S}{1,5} Ip \cdot (h - h_c) \text{ with } \eta_0 < 1°$$

**For a TBV unit with a passive system** subjected to a cant deficiency IP the quasi-static displacements are:

$$Z_P = \frac{S}{1,5} Ip \cdot (h - h_c) \text{ with } \eta_0 < 1°$$

It is necessary to draw attention to the fact that the value of *s* is specific to the situation calculated and can, therefore, be influenced by the action of the body tilt system.

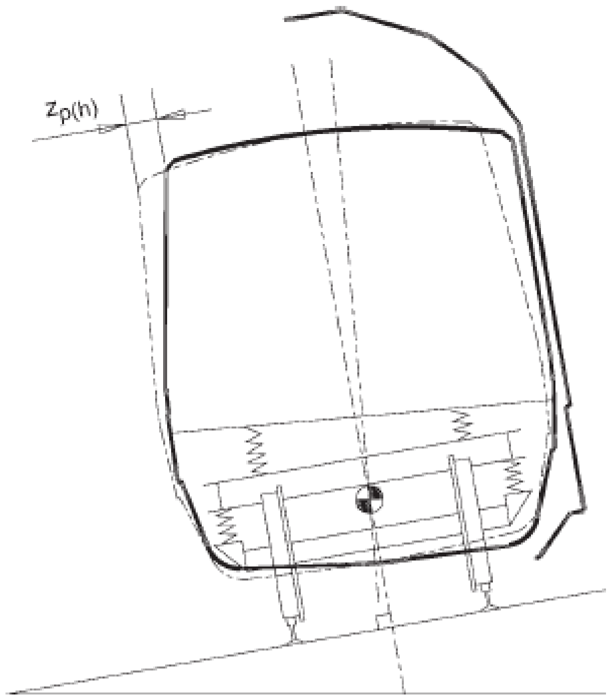
**C.8.3.2.2.2 Expression of the quasi-static displacements zP, fort he reductions on the outer side of the curve**

Under the effect of the lateral acceleration (corresponding to values IP>0) the body of an active TBV unit tilts towards the outside of the curve because of the flexibility of the suspension system and towards the inside of the curve for a passive TBV unit.

Similarly to Figures 2a and 2b, the Figures 3a and 3b represent this type of displacement, from the position I = 0.

*Fig. C34:*

ACTIVE system



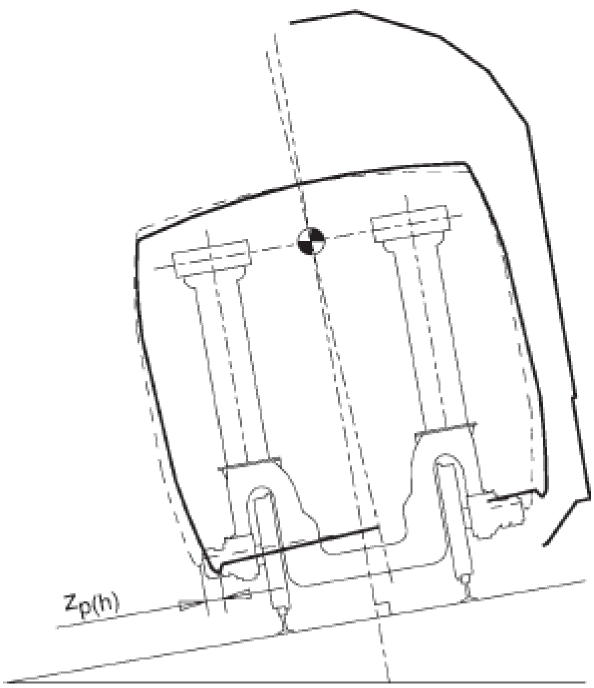

**Note:**

The tilt imparted by the system is not represented here.

- Since the reference profile is considered from the standpoint of the outside of the curve, the points of the vehicle situated at a height h>hc move closer to the profile. The value of this displacement in the calculation will have a plus sign.
- The opposite is true for the points situated at a height of h < hc.

*Fig. C35:*

**PASSIVE system**




- Since the reference profile is considered from the standpoint of the outside of the curve, the points of the vehicle situated at a height h<hc move closer to the profile. The value of this displacement in the calculation will have a plus sign.
- The opposite is true for the points situated at a height of h > hc.

When the vehicles run in a curve they move closer to the reference profile (on the outer side) in proportion to the value of IP; if the condition IP >IC, is present, the distances considered by the Permanent Way Department for the positioning of obstacles will not be sufficient. Since the position of obstacles cannot be questioned, the reductions calculated for vehicles should, if necessary, be increased by a value corresponding to the difference between the quasi-static displacements due to IP and those taken into account by the Permanent Way Department or:

Active system

$$z = \left[\frac{s}{1{,}5}.I_P.(h-h_c) - \frac{0{,}4}{1{,}5}.(I_c - 0{,}05).(h-0{,}5)_{>0}\right]_{>0}$$

Passive system

$$z = \left[-\frac{s}{1{,}5}.I_P(h-h_c) - \frac{0{,}4}{1{,}5}.(I_c - 0{,}05).(h-0{,}5)_{>0}\right]_{>0}$$

It must be remembered that:

- the formulae apply where IP > IC;
- it will be necessary to find in the application phase corresponding to a real case, the combination of the values for IP and IC which give a value of zP that maximises the reduction:
- the tilting system of the vehicle must ensure the following for the intermediate values of IP (marked IP'), to which correspond the intermediate values of cant deficiency Ic':

$$I'_p \leq \frac{I_p}{I_c} . I'_c$$

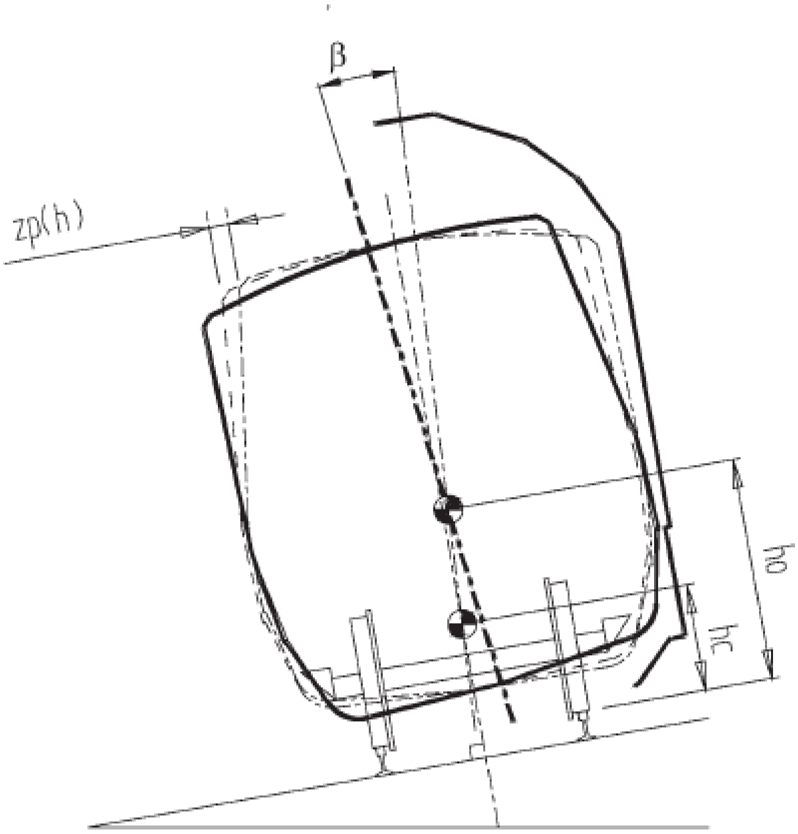
Furthermore, the conditions given in 5.1 must be met.

**C.8.3.2.3 ACTIVE systems: displacements due to body rotation**

When an active-system TBV runs over a curve at a speed such that IP>0, based on measurement of the value of certain parameters (speed, cant gradient, curve radius) the tilting system establishes the angle of body tilt β.

The angle β is independent of the tilt due to the flexibility of the suspensions.

*Fig. C36*




n Figure 4 the following values are represented:

**ho**: height of the centre of rotation of the body imposed by the system.

**β**: value of the angle of body tilt, relative to the system bearing plane; this angle imposed by the system is a function of the cant deficiency IP.

Since angle β can be as great as 10o, the vertical component of the displacement must not be overlooked and it shall be taken into account in the calculation for real cases.

If only the lateral displacements are considered, approximate values can be found by the following formula:

$\tan \beta \, (h - h_0)$

This term, in light of the direction of rotation imposed by the system,

- shall carry a positive sign in the calculations on the inside of the curve
- shall carry a minus sign in the calculations on the outside of the curve.

## C.8.4 ASSOCIATED RULES

- The formulae apply for IP > IC.
- The expression of the term zP shall be detailed and explained, case by case, when the formulae are applied to each type of system, bearing in mind the different stops, the roll centre, etc.
- It should be stressed that the parameters, s, $h_c$ and w, in agreement with the technical principles of the TBV unit, for any given vehicle have different values depending on the calculation cases involved.
- The maximum values of the reductions shall be calculated depending on the different values likely to be taken by IP, IC (and by the angle β for active TBVs, see § 3.2.3). For this purpose the TBV Builder should bear in mind the most prominent places permitted on the bodies when running over different sections of line (straight track, transitions, curves) and the possible tolerances with respect to the effective position of the vehicle (due to the delay in system activation, inertia, friction, etc).
- The parts of the TBVs which are not connected to the body and, therefore, do not tilt, always remain subject to a value of uncompensated acceleration greater than that normally accepted. For these items (such as the bogies and sometimes the pantograph), a supplementary term taking account of the reduction shall be used when the tilting body is checked.

This term is of the form:

$$\frac{S}{1,5}(I_p - I_c)(h - h_c)$$

Moreover, no account shall be taken of the term tan β (h - $h_0$) for these parts (see § 3.2.3).

- This Appendix has been developed on the basis of information applicable to the TBV units in service today. Other hypotheses and modifications to the formulae may be added, in the future, after new types of TBV units have been developed.
- When the examination of all the cases which were thought to be critical has been completed, a comparison shall be made between the different permissible half-width dimensions and the smallest value at each of the heights h considered shall be selected.

## C.8.5 COMMENTS

### C.8.5.1 Condition for adjusting the inclination (TBV units with active system)

For the formulae that have been given in this Appendix for the calculation of the loading gauge of TBV units to be valid it is necessary that the tilt system guarantees that the body is inclined in a way that is proportional to the variation of the cant deficiency.

For the passive systems this condition is obviously fulfilled as the tilt of the body is caused by the low cant.

For TBV units with an active tilt system on the other hand, the values that the system imposes on the bodies are fixed by the design or adjustment of the system.

These values shall meet the following conditions in order that the bodies do not exceed the specified profile:

a) The intermediate values I'P, I'C and E' between 0 and the maximum value of the respective sizes, shall meet, from a point of view of the regulation of the tilting system, the following condition:

$$\frac{I'_P}{I_P} = \frac{I'_C}{I_C} = \frac{E'}{E}$$

b) Moreover in the case of checking on the outside of the curve, in view of the fact that the centrifugal force tilts the body towards the outside (quasi-static displacement zP), the following condition, regarding the value of β for the adjustment shall be observed:

$$\tan \beta \, (h - h_0) \geq z_p$$

In other words, the effect of the system must be greater than or equal to the quasi-static effect.

**C.8.5.4 Condition concerning the speed of TBV units**

For TBVs, it is permissible to calculate a maximum speed from the standpoint of the loading gauge than for other vehicles.

Reference should be made to the expression that relates the cant deficiency to the speed:

$$I_{PorC} = 0{,}01186 \frac{V^2_{PorC}}{R} - E$$

The speeds vP and vC are respectively the value taken by the TBV and the corresponding value allowed for the track, according to the ruling speed for the line.

$$\text{Thus: } V_P \leq \sqrt{\frac{I_P + E}{I_C + E}} V_C$$

From this formula, it is possible to deduce the maximum speed value that must not be exceeded by the TBV, using the following formula:

$$V_P \leq \sqrt{\frac{I_P + E}{I_C + E}} V_C$$

## C.8.6 APPENDIX 4 ROLLING STOCK LOADING GAUGE

Use of existing infrastructure clearances by vehicles with predefined parameters

A bilateral agreement shall be required before applying this appendix.

Example:

On straight track in good maintenance condition with the usual defects in track geometry, the decisive criterion shall be the maximum distance between track centres; this equals the width of the reference profile plus margins for random movements of the vehicle due to defects in track geometry (D).

$$D = \sqrt{d_i^2 + d_a^2}$$

$$d_{i,a} = 1{,}2 \sqrt{\Sigma t_{i,a}^2}$$

$$t_i \Big|_{i=1}^{i=5}$$

$$t_a \Big|_{a=1}^{a=5}$$

$t_1$ = lateral movement of the track

$t_2$ = impact of a cant or cross-level defect of 0,015 m

$t_{3i,\,a}$ = oscillations towards the inside or towards the outside

$t_4$ and $t_5$= impact of load imbalance and of asymmetries

$t_1 = 0{,}025$

$$t_2 = 0{,}15\frac{h}{1{,}5} + 0{,}015(h - h_C)\frac{S}{1{,}5}$$

$$t_{3,i} = 0{,}007(h - h_C)\frac{S}{1{,}5}$$

$$t_{3,a} = 0{,}039(h - h_C)\frac{S}{1{,}5}$$

$$t_4 = 0{,}05(h - h_C)\frac{S}{1{,}5}$$

$$t_5 = 0{,}015(h - h_C)\frac{S}{1{,}5}$$

The following parameters shall be used to determine the margins (clearances) to be added to the G1 reference profile:

h = 3,25 m

$h_c$ = 0,5 m

s = 0,4

The predefined parameters of the vehicle under examination can be used, for instance:

h = 1,8 m (height above the running surface of a certain body section)

$h_c$ = 0,7 m

s = 0,24

Based on the above parameters, the following values can be obtained:

– for profile G1 D = 0,113 m
– for the vehicle with predefined parameters D’ = 0,058 m

The difference D - D’ = 0,055 m can be used as a basis for widening a vehicle with predefined parameters.

If the additional clearance covering random movements is not calculated as described, but a flat overall value is defined, and if this results in smaller dimensions, this should be taken into consideration for the calculation of D-D’.

Example: SNCF, V ≤ 120 km/h: $D_{SNCF}$ = 0,05 + 0,03 = 0,08 m.

The vehicle with predefined parameters could then be widened by 0,022 m at a height of 1,8 m.