BS EN 50367:2020+A2:2025

BSI Standards Publication

Railways applications — Fixed installations and rolling stock — Criteria to achieve technical compatibility between pantographs and overhead contact line

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National foreword

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The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CENELEC text carry the number of the CENELEC amendment. For example, text altered by CENELEC amendment A1 is indicated by ▌A1⟩ ⟨A1▌.

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

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31 March 2025	Implementation of CENELEC amendment A2:2025

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NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50367:2020+A2

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English Version

Railway applications - Fixed installations and rolling stock - Criteria to achieve technical compatibility between pantographs and overhead contact line

Applications ferroviaires - Systèmes de captage de courant - Critères techniques d'interaction entre le pantographe et la ligne aérienne de contact (réalisation du libre accès)

Bahnanwendungen - Zusammenwirken der Systeme - Technische Kriterien für das Zusammenwirken zwischen Stromabnehmer und Oberleitung für einen freien Zugang

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

This document (EN 50367:2020) has been prepared by CLC/SC 9XC “Electric supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations)”.

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

Annex B gives some parameters for existing lines (informative).

Compared with the previous version, the most significant changes in this version are:

- Update of definitions;
- Changes to 5.2.5 concerning the lateral deviation on the basis of RfS 51 from the European Union Agency for Railways;
- Changes in 5.2.7;
- Revision of 5.3.2, including update of figures;
- Improvement of testing method for DC contact strips: 6.3, A.3;
- Addition of tunnel requirements in Clause 7;
- Revision of Table 9;
- Assessment requirements in Clause 9;
- Addition of an introduction for Annex B;
- Addition of Annex C;
- Addition of Annex D.

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European foreword to Amendment 1

This document (EN 50367:2020/A1:2022) was prepared by SC 9XC, "Electric supply and earthing systems for public transport equipment and ancillary apparatus (fixed installations)", of CLC/TC 9X, "Electrical and electronic applications for railways".

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European foreword to Amendment 2

This document (EN 50367:2020/A2:2025) was prepared by SC 9XC, "Electric supply and earthing systems for public transport equipment and ancillary apparatus (fixed installations)", of CLC/TC 9X, "Electrical and electronic applications for railways".

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1 Scope

This document specifies requirements for the technical compatibility between pantographs and overhead contact lines, to achieve free access to the lines of the European railway network.

NOTE These requirements are defined for a limited number of pantograph types conforming to the requirements in 5.3, together with the geometry and characteristics of compatible overhead contact lines.

2 Normative references

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

EN 15273-1:2013+A1:2016, *Railway applications - Gauges - Part 1: General - Common rules for infrastructure and rolling stock*

EN 15273-2:2013+A1:2016, *Railway applications - Gauges - Part 2: Rolling stock gauge*

EN 15273-3:2013+A1:2016, *Railway applications - Gauges - Part 3: Structure gauges*

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

EN 50125-2:2002, *Railway applications - Environmental conditions for equipment - Part 2: Fixed electrical installations*

EN 50149:2012, *Railway applications - Fixed installations - Electric traction - Copper and copper alloy grooved contact wires*

EN 50206-1:2010, *Railway applications - Rolling stock - Pantographs: Characteristics and tests - Part 1: Pantographs for main line vehicles*

EN 50317:2012, *Railway applications - Current collection systems - Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line*

EN 50318:2018, *Railway applications - Current collection systems - Validation of simulation of the dynamic interaction between pantograph and overhead contact line*

EN 50388:2012, *Railway Applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability*

EN 50405:2015, Railway applications – Current collection systems – Pantographs, testing methods for contact strips[1)]

A1 *Text deleted.* A1

[1)] This standard is impacted by EN 50405:2015/A1:2016.

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3 Terms and definitions

A1 For the purposes of this document, the following terms and definitions apply.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp A1

3.1
arcing
flow of current through an air gap between a contact strip and a contact wire usually indicated by the emission of intense light

[SOURCE: EN 50317:2012, 3.17]

3.2
pantograph dropping device
device intended to lower the pantograph automatically if it is damaged

Note 1 to entry: The damage can include the contact strip, the pantograph head and other parts of the pantograph.

[SOURCE: IEC 60050-811:2017, 811-32-22, modified – In the Note 1 to entry, “and” between “strip” and “the pantograph” has been replaced by a comma, and the comma between “and” and “other” has been removed]

3.3
contact force
<for a pantograph> vertical force applied by the pantograph to the contact wire(s)

Note 1 to entry: The contact force is the sum of forces of all contact points of a pantograph.

Note 2 to entry: The contact force is measured perpendicular to the contact plane.

[SOURCE: EN 50318:2018, 3.2, modified – The Note 2 to entry has been added]

3.4
contact plane
plane parallel to the base frame of the pantograph at the contact point

3.5
contact point
<for a pantograph> point of the mechanical contact between a contact strip and a contact wire

[SOURCE: EN 50317:2012, 3.2, modified – The specific domain has been added in the definition]

3.6
contact wire height
distance from the top of the rail level to the lower face of the contact wire.

Note 1 to entry: The contact wire height is measured perpendicular to the track surface.

[SOURCE: IEC 60050-811:2017, 811-33-62, modified – “or road surface for trolleybus (811-02-43) has been removed. In the Note 1 to entry, “or road” has been removed]

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3.7
pantograph head
part of the pantograph comprising the contact strips and their mountings, horns and possibly a suspension

[SOURCE: IEC 60050-811:2017, 811-32-05]

3.8
continuous pantograph head profile
pantograph head with collector strips and horns suspended in one piece

3.9
encroachment of the pantograph head
perpendicular distance from the contact plane to the highest point of the pantograph head

Note 1 to entry: Additional information is given in EN 15273-1:2013+A1:2016, Figure 46.

3.10
maximum contact wire height
maximum value of the contact wire height above rail level occurring in any possible case during the lifetime of the overhead contact line

[SOURCE: IEC 60050-811:2017, 811-33-65]

3.11
maximum design contact wire height
⟨A1⟩ theoretical contact wire height taking account of tolerances, movements, etc., designed to ensure the maximum contact wire height is not exceeded

[SOURCE: EN 50119:2020, 3.1.5.8] ⟨A1⟩

3.12
maximum width of pantograph head
maximum distance measured along the axis of the track between the outer edges of the contact strips

3.13
mean contact force
F_m
statistical mean value of the contact force

Note 1 to entry: F_m is formed by the static and aerodynamic components of the pantograph contact force.

Note 2 to entry: This mean value can be assessed by simulation or measurement over a specified time or distance.

[SOURCE: EN 50317:2012, 3.5, modified – The Note 2 to entry has been added]

3.14
mechanical kinematic pantograph gauge
gauge of the pantograph head under all operating conditions

Note 1 to entry: Additional information is given in EN 15273-1:2013+A1:2016, 3.23.

3.15
minimum contact wire height
minimum value of the contact wire height above rail level occurring in any possible case during the lifetime of the overhead contact line

[SOURCE: IEC 60050-811:2017, 811-33-64]

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3.16
neutral section
section of a contact line provided with a sectioning point at each end, to prevent successive electrical sections differing in voltage, phase or frequency being connected together by the passage of pantographs

[SOURCE: IEC 60050-811:2017, 811-36-16, modified - “current collectors” has been replaced by “pantographs”]

3.17
nominal contact wire height
nominal value of the contact wire height above rail level at a support in the normal conditions

[SOURCE: IEC 60050-811:2017; 811-33-63]

3.18
non-continuous pantograph head profile
pantograph head with collector strips separately (independently) suspended from the other parts of the pantograph head

3.19
overhead contact line
contact line placed above the upper limit of the vehicle gauge and supplying vehicles with electric energy through pantographs

[SOURCE: IEC 60050-811:2017, 33-02, modified – “or beside” has been removed and “roof-mounted current collection equipment” has been replaced by “pantographs”]

3.20
percentage of arcing
NQ
proportion of driving time with arcing

[SOURCE: EN 50317:2012, 3.20]

3.21
static contact force
vertical force exerted upward by the pantograph head on the overhead contact line at standstill

[SOURCE: EN 50206-1:2010, 3.3.5, modified - “collector head” has been replaced by “pantograph” and “system” has been removed]

3.22
transition zone
<of pantograph head> range for the transition point between non-independently suspended parts and independently suspended parts of the pantograph head

Note 1 to entry: This concept is illustrated in Figures 1 and 2 of this document

3.23
working range of the height of pantograph
range of permissible heights of contact points in relation to the track level

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3.24
limit of dewirement
b_V
maximum permissible lateral deviation of contact wire position from pantograph head centre to prevent dewirement (limit of stability for lateral interaction between contact wire and pantograph, described by the transition point at head profile, where the angle exceeds 40°)

Note 1 to entry: Dewirement (i.e. lateral contact loss between contact wire and pantograph head) is not the only cause of pantograph head / overhead contact line incidents. Other phenomena can lead to incidents, without exceeding dewirement limits, as described now in this document.

3.25
working zone of pantograph head
lateral range of the contact point at the pantograph head for operation under normal conditions (serviceability)

3.26
reference height
<of contact point> height of the contact point used for calculation of lateral position of contact wire at the pantograph head

3.27
traction unit
locomotive, motor coach or train-unit

Note 1 to entry: A train can be formed with multiple traction units.

[SOURCE: IEC 60050-811:2017, 811-02-04, modified – The Note 1 to entry has been added]

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

A	inner distance between the contact strips on successive operational pantograph heads [m]
A'	outer distance between the contact strips on the first and last operational pantograph heads [m]
A''	inner distance between the contact strips of one and the second following operational pantograph head [m]
AC	Alternating Current
$b'_{h,mec}$	width of mechanical kinematic pantograph gauge at reference height for interaction between contact wire and pantograph [m] (inclusive of tolerances of overhead contact line)
$b'_{o,mec}$	width of mechanical kinematic pantograph gauge at maximum verification height of the pantograph gauge in a raised position [m] (inclusive of tolerances of overhead contact line)
$b'_{u,mec}$	width of mechanical kinematic pantograph gauge at minimum verification height of the pantograph gauge in a raised position [m] (inclusive of tolerances of overhead contact line)
$b'_{h,OCL}$	width of mechanical kinematic gauge for serviceability of overhead contact line at reference height for interaction between contact wire and pantograph [m]
$b'_{u,OCL}$	width of mechanical kinematic gauge for serviceability of overhead contact line at minimum verification height of the pantograph gauge in a raised position [m]
b_V	maximum permissible lateral deviation of contact wire position from pantograph head centre to prevent dewirement [m]
b_W	half-length of the pantograph head [m]

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$b_{w,c}$	half-length of the pantograph head conducting length (with insulating horns) or working length (with conducting horns) [m]
CL	Conventional Line
d	dimension over wheel flanges at wear limit measured 10 mm below the wheel tread [m]
d_{cant}	lateral movement of contact wire caused by forces from tilted pantograph due to tracks with cant [m]
d_{instl}	tolerance of static lateral position of contact wire [m]
d_{instv}	tolerance of static vertical position of contact wire [m]
d_l	permissible lateral deviation of contact wire from track centre line [m]
d_{lstab}	permissible lateral deviation of contact wire from track centre for stability against dewirement [m]
d_{lserv}	permissible lateral deviation of contact wire from track centre line to meet the serviceability limit state [m]
d_{meas}	tolerance of measurement, measuring errors refer to lateral position of contact wire [m]
d_{pole}	lateral deviation of contact wire position resulting from change of pole deflection under additional load due to wind speed, for serviceability at nominal contact wire height [m]
d_{supp}	lateral deviation of contact wire position resulting from movement of cantilever for change in wire temperature [m]
d_{tens}	lateral deviation of contact wire position resulting from reduced tension force of wires considering efficiency of tensioning devices [m]
D	overall length of neutral section as distance between adjacent systems/phases including overlapping parts taking into account the uplift by pantograph passage and electrical clearances in accordance with EN 50119:2020, 5.1.3 [m]
DI'_o	reference cant, which is the maximum value from cant and cant deficiency [m]
D'	length of neutral section excluding overlapping parts taking into account the uplift by pantograph passage and electrical clearances in accordance with EN 50119:2020, 5.1.3 [m]
D_0	fixed cant value defined taken into account kinematic gauge [m]
DC	Direct Current
e_{po}	offset of the pantograph at the upper verification point [m]
e_{pu}	offset of the pantograph at the lower verification point [m]
e_{phref}	pantograph sway at the reference height for interaction between contact wire and pantograph [m]
F_m	mean contact force [N]
F_{max}	maximum contact force [N]
$F_{m,\,min}$	minimum mean contact force [N]
$F_{m,\,max}$	maximum mean contact force [N]
F_{min}	minimum contact force [N]
F_{stat}	static contact force [N]
f_s	maximum uplift of contact wire within the span length [m]
h_{c0}	value of roll centre height used as interface between the rolling stock and the infrastructure [m]

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h_{nom}	nominal contact wire height [m]
h'_o	maximum verification height of the pantograph gauge in a raised position [m]
h'_u	minimum verification height of the pantograph gauge in a raised position [m]
h_{ref}	reference height for interaction between contact wire and pantograph [m]
HSL	High Speed Line
I'_0	fixed cant deficiency value taken into account as interface between the rolling stock and the infrastructure with regard to the kinematic gauge of the pantographs [m]
k'	factor of safety to take into account track irregularities, for pantograph gauge being considered
K_{eff}	efficiency of tensioning devices
l	maximum width of pantograph head [m]
l_{max}	maximum track gauge [m]
L_{sp}	maximum design span length of overhead contact line [m]
NQ	percentage of arcing
$qs'_{i/a}$	displacement due to the quasi-static roll, as maximum from the values to inside and outside the curve, for pantograph gauges [m]
OCL	overhead contact line
Q_{wc}	wind load on catenary [N]
R	horizontal curve radius [m]
S_c	sum of tension forces of catenary and contact wires [N]
$S'_{i/a}$	displacement due to additional overthrow as maximum from the values to inside and outside the curve, for pantograph gauges [m]
s'_0	flexibility coefficient taken into account as interface between the rolling stock and the infrastructure for the pantograph gauge
T_{charge}	angle of dissymmetry, considered in η for poor load distribution [degree]
T_D	track cross-level difference between two maintenance periods [m]
T_{osc}	cross-level difference selected for calculation of oscillations caused by track irregularities [m]
T_{susp}	angle of dissymmetry, considered in η for poor suspension adjustment [degree]
T_{voie}	transverse displacement of the track between two periods of maintenance [m]
d_{up}	lateral movement of contact wire caused by forces from non-horizontal sections of pantograph head [m]
v	permitted train speed with a specific overhead contact line [km/h]
w	distance between parts of different potentials of insulator inserted in contact wire [m]
σ_{max}	maximum standard deviation of contact force
α	angle of independent suspended part of the pantograph head at the transition point [degree]
β	angle of the main horn on the fixed part of the pantograph head [degree]
γ	angle of the horn of the pantograph head [degree]
η	reference value for angle of dissymmetry of a vehicle due to suspension adjustment and to unequal load distributions [degree]

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Σj	sum of (horizontal) allowances for the structure gauge, covering certain random phenomena (j = 1, 2 or 3) [m]
$\sum T_{Thref}$	total of all tolerances of track at the reference height for interaction between contact wire and pantograph [m]
$\sum T_o$	total of all tolerances of track and overhead contact line at the upper verification point [m]
$\sum T_u$	total of all tolerances of track and overhead contact line at the lower verification point [m]
$\sum T_{OCL}$	total of all tolerances of overhead contact line [m]
$\sum T_{To}$	total of all tolerances of track at the upper verification point [m]
$\sum T_{Tu}$	total of all tolerances of track at the lower verification point [m]

5 Geometry

5.1 General

[A1] This Clause provides requirements for geometric limits of pantographs preventing dewirement and allowing for adequate interaction performance.

The overhead contact line shall be designed and built in accordance with the geometric characteristics given in 5.2. The pantograph(s) shall be designed and manufactured in accordance with the geometric characteristics given in 5.3 and compatible with the type of infrastructure on which it will operate. [A1]

The requirements in Clause 5 [A1] apply [A1] to standard gauge applications in accordance with EN 15273-1:2013+A1:2016, EN 15273-2:2013+A1:2016 and EN 15273-3:2013+A1:2016. These requirements can be adapted to other track gauges.

5.2 Overhead contact line characteristics

5.2.1 General

The following geometric parameters of the overhead contact line are defined in order to assess technical compatibility with pantographs whose geometric characteristics are defined in 5.3

- kinematic gauge;
- contact wire height;
- contact wire gradient;
- lateral deviation of the contact wire from the track centre line under action of a crosswind;
- free and unrestricted contact wire uplift at the support;
- neutral section arrangements.

The overhead contact line shall conform to the requirements set out in EN 50119:2020, 5.10.

5.2.2 Infrastructure gauge for free passage of pantograph

The design of the overhead contact line shall allow the operation of vehicles compliant to the appropriate vehicle gauge for the route. This gauge shall be calculated in accordance with EN 15273-1:2013+A1:2016, EN 15273-2:2013+A1:2016 and EN 15273-3:2013+A1:2016.

The gauge for free and unrestricted passage of pantographs shall be calculated based on the kinematic gauge for pantographs in accordance with EN 15273-3:2013+A1:2016, Clause 11. Electrical clearances requirements shall be as set out in EN 50119:2020, 5.1.3.

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NOTE 1 This calculation covers the lateral movement of the pantograph, the encroachment of the pantograph, the track gauge and the tolerances.

The design of infrastructure gauge shall allow for unrestricted passage of pantographs with profiles as set out in Figure A.6 or pantographs with either insulating or conductive horn as set out in Figure A.7.

The determination of the minimum height of structures above the contact line shall be in accordance with EN 15273-1:2013+A1:2016, 8.1.2. For this, the encroachment of the pantograph head above the contact plane defined in 5.3.1, ⟨A1⟩ may ⟨A1⟩ be reduced by taking into consideration the maximum possible lateral position at this location.

NOTE 2 As an example, for bridges the maximum encroachment can be adjusted if the nominal position of contact wire is at the track centre line.

5.2.3 Contact wire height

The nominal contact wire height shall be chosen inside the ranges given in Table 1.

The contact wire may be higher in certain cases such as level crossings, loading areas, etc. In these cases, the maximum design contact wire height shall not be greater than 6,20 m.

The maximum contact wire height shall not exceed 6,50 m.

The contact wire height may be lower than the nominal contact wire height in certain cases related to structure gauges such as bridges and tunnels. Contact wire height shall be within the limits calculated in accordance with EN 50119:2020, 5.10.

NOTE Aerodynamic effects could necessitate to limit the contact wire height for speed higher than 250 km/h in order to achieve technical conformity for new traction units.

Table 1 — Contact wire height and gradient for AC and DC systems

Line speed *v* [km/h]	**v < 250**	**v ≥ 250**
Range of nominal contact wire height [m]	from 5,0 up to 5,75	from 5,08 up to 5,3
Permissible gradient and change of gradient	in accordance with EN 50119:2020, Table 12	⟨A1⟩ in accordance with EN 50119:2020, Table 12 ⟨A1⟩

5.2.4 Contact wire gradient

The permissible contact wire gradient and change of gradient shall be in accordance with Table 1.

The contact wire gradient specified in Table 1 may be exceeded on an exceptional basis, where a series of restrictions on the contact wire height such as level crossings, bridges, tunnels, etc., prevents compliance. In this case the assessments requirements of 7.3 shall be replaced by the limits as set out in Table 4 of EN 50119:2020.

5.2.5 Lateral deviation of contact wire

5.2.5.1 General

The permissible lateral deviation of the contact wire from the track centre line is calculated based on the working zone of pantograph head for serviceability and on the limit of dewirement (the limit of stability for lateral interaction).

NOTE 1 Under standard conditions the contact between contact wire and pantograph is inside the limits of serviceability.

NOTE 2 Under worst conditions, contact inside the limits of dewirement can occur without damages with catastrophic consequences.

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For checking the stability against dewirement, the permissible lateral deviation of contact wire from track centre line (d_{lstab}) shall be calculated in accordance with 5.2.5.2.

For checking the lateral deviation for serviceability, the permissible lateral deviation of contact wire from track centre line (d_{lserv}) shall be calculated in accordance with 5.2.5.3.

The permissible lateral deviations shall be calculated in accordance with EN 15273-1:2013+A1:2016, EN 15273-2:2013+A1:2016 and EN 15273-3:2013+A1:2016, considering the movements of pantographs and track gauge using the reference values set out in EN 15273-1:2013+A1:2016, Table G.1 and EN 15273-3:2013+A1:2016, Table B.1.

For pantographs according to 5.3, the maximum limit for permissible lateral deviation of the contact wire from the design value for track centre line, under the action of cross wind shall be defined as minimum of:

— d_{lstab} (5.2.5.2)

— d_{lserv} (5.2.5.3) and

— the limit given in Table 2.

Table 2 — Limit of lateral deviation

Pantograph head length [mm]	Limit of lateral deviation [mm]
1 600	400
1 950	550

NOTE 3 These limits are defined based on long term experiences of the different railways when defining interoperability.

In the case of a mixed-gauge track (track with three rails), the requirement shall be fulfilled for each pair of rails (designed to be operated as separate track).

[A1] The wind speeds and pantograph head lengths used to calculate the limit of lateral deviation shall be defined. [A1]

An example of calculation is given in informative Annex D.

For a visualization of lateral deviation see D.5.

5.2.5.2 Limit of dewirement – limit of stability for lateral interaction

The limit of dewirement shall be determined based on the kinematic envelope of the pantograph taking into consideration the tolerances of the overhead contact line and the horizontal movement of the contact wire caused by forces from the non-horizontal sections of the pantograph head.

The horizontal movement of the contact wire shall be calculated for the application of the maximum mean contact forces.

NOTE 1 Stability is achieved when the contact wire position on the pantograph head lies between pantograph head centre line and the point of dewirement – see A.2.

The permissible lateral deviation of the contact wire from track centre line to prevent dewirement shall be calculated as:

$$d_{lstab} = b_{\mathrm{W}} + b_{\mathrm{V}} - b'_{h,mec} = b_v - \left(e_{phref} + \frac{s'_i}{a} + \frac{qs'_i}{a} \right) - k' \cdot \sqrt{\sum T_{Thref}{}^2 + \sum T_{OCL}{}^2} \qquad (1a)$$

The calculation shall be done for the reference height (h_{ref}) for the interaction between contact wire and pantograph.

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$$b'_{h,mec} = b'_{u,mec} + \frac{\left(h_{ref} - h'_u\right)}{\left(h'_o - h'_u\right)} \cdot \left(b'_{o,mec} - b'_{u,mec}\right) \quad (1b)$$

The term ($\sqrt{\sum T_{Thref}{}^2 + \sum T_{OCL}{}^2}$) applies the tolerances of the overhead contact line with the same methodology as used in EN 15273-1:2013+A1:2016, EN 15273-2:2013+A1:2016 and EN 15273-3:2013+A1:2016 for calculation of Σj.

NOTE 2 Possible index of *j* can be 1, 2 or 3 in accordance with EN 15273-3:2013+A1:2016, 5.5.2.

For the purpose of interoperability, the value of index chosen for *j* shall be 2.

The reference height (h_{ref}) shall be the summation of the nominal contact wire height, uplift and the construction tolerances for the overhead contact line.

$$h_{ref} = h_{nom} + f_s + d_{instv} \quad (2)$$

NOTE 3 Encroachment of pantograph head is not considered for this calculation.

NOTE 4 The value of f_s is dependent upon the overhead contact line design and can be calculated, simulated or measured.

The limit of dewirement shall be calculated considering the following parameters of construction and operation of the overhead contact line:

— tolerance of static lateral contact wire position (installation and maintenance) d_{instl};

— change of mast deflection under additional load due to wind speed for normal operation conditions in nominal contact wire height d_{pole};

— lateral movement of contact wire caused by forces from tilted pantograph due to tracks with cant d_{cant};

— lateral deviation of contact wire caused by movement of cantilever due to wire expansion and contraction by changes in wire temperature d_{supp};

— increased lateral deviation of contact wire for reduced tension force of wires considering efficiency of tensioning devices and effects of along track movement of registration arms or cantilever frames d_{tens};

— tolerance of the measurement system d_{meas};

— lateral movement of contact wire due to the interaction with the upward forces from non-horizontal sections of pantograph head d_{up}.

Those tolerances which can occur simultaneously shall be added using following formula:

$$\Sigma T_{OCL} = k' \cdot \sqrt{(d_{instl}{}^2 + d_{pole}{}^2 + d_{cant}{}^2 + d_{supp}{}^2 + d_{meas}{}^2 + d_{tens}{}^2 + d_{up}{}^2)} \quad (3)$$

NOTE 5 With regard to probabilistic addition, see EN 15273-1:2013+A1:2016, Annex J.

The safety coefficient *k'* shall be chosen to achieve the required safety level, for which, a value of 1,0 is recommended (see EN 15273-3:2013+A1:2016, Table B.1).

The lateral movement of contact wire caused by forces from the non-horizontal sections of pantograph head shall be calculated as:

$$d_{up} = L_{sp} \cdot F_{m,max} \cdot \tan \gamma / (4 \cdot S_c) \quad (4)$$

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where

L_{sp} is the maximum span length;

$F_{m,max}$ is the design limit for mean contact force according to Table 6 or Table 7;

γ is 30° for pantograph heads according to Figure A.6 or 40° for pantograph heads according to Figure A.7;

S_c is the sum of the tension forces in contact wire and messenger wire.

NOTE 6 The use of sum of the tension forces considers the interaction between the wires in the overhead contact line connected with droppers.

5.2.5.3 Serviceability limit state

The permissible lateral deviation of the contact wire from track centre line to meet the serviceability limit state, shall be calculated based on the kinematic gauge $b'_{h,mec}$ in accordance with EN 15273-1:2013+A1:2016, EN 15273-2:2013+A1:2016 and EN 15273-3:2013+A1:2016., as:

$$d_{lserv} = b_w + b_{w'c} - b'_{hOCL} = b_{w,c} - \left(e_{phref} + S'_{i/a} + qs'_{i/a}\right) \tag{5}$$

where

$$b'_{hOCL} = b'_{uOCL} + \frac{\left(h_{ref} - h'_u\right)}{\left(h'_o - h'_u\right)} \cdot \left(b'_{oOCL} - b'_{uOCL}\right) \tag{6}$$

$$b'_{uOCL} = b_w + e_{pu} + S'_{i/a} + qs'_{i/a} \tag{7}$$

$$b'_{oOCL} = b_w + e_{po} + S'_{i/a} + qs'_{i/a} \tag{8}$$

The calculation of lateral deviation of the contact wire shall be done for a reference height h_{ref} according to 5.2.5.2 of this standard. For this calculation, the sum of additions of the probabilistic safety margins for $\sum_j$ shall not be considered.

NOTE The summation of the probabilistic safety margins is not considered for normal operation conditions (serviceability). In these cases the contact point may be located outside the working range of pantograph head with arcing and current interruption without causing dewirement.

5.2.6 Contact wire uplift

The permissible contact wire uplift at supports shall be in accordance with EN 50119:2020, 5.10.2.

5.2.7 Neutral sections

The electrical requirements for operation through neutral sections are set out in EN 50388:2012, Clause 5. For the mechanical design the following requirements of neutral sections shall be considered:

- trains shall be able to move from one section to an adjacent one (which is fed from a different phase or system) without bridging the neutral section;
- the neutral section shall be designed in such a way that trains with multiple pantographs arranged in accordance with A.1, with an outer distance between the contact strips on the first and last operational pantograph heads up to a maximum of 400 m, can pass through with their pantographs raised;
- A1 adequate means shall be provided to allow a train that is stopped within the neutral section to be restarted, except for short neutral sections as set out in Annex A, A.1.3. A1

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[A1] *Text deleted.* [A1]

In the case of trains with multiple pantographs, if one of these requirements cannot be complied with, the pantographs shall be lowered for the entire length of the neutral section. Technical or operational measures shall be taken to meet safety and availability requirements.

The operational requirements for the arrangements of pantographs on trains are set out in 8.2.

5.2.8 Change over area between pantograph profiles

Where two different types of OCLs intersect, which are designed for different pantograph profiles, a changeover area shall be provided. In the changeover area, one pantograph type shall be lowered and the other type shall be raised. Within the changeover area which is common to the different pantograph profiles, the overhead contact line shall be designed as follows:

- the lateral deviation of the contact wire in accordance with 5.2.5, shall be calculated for the pantograph with the shortest length of head;
- the pantograph gauge in accordance with 5.2.2, shall be calculated for the pantograph with the longest length of pantograph head.

The new pantograph shall not be raised before the other is lowered.

NOTE Lowering of a pantograph before raising another one is necessary to avoid a critical uplift of the contact wire and unexpected high contact forces.

5.3 Pantograph characteristics

5.3.1 General

The following geometric parameters of the pantograph shall be assessed to achieve compatibility with the infrastructure:

- geometric profile of pantograph head;
- vertical working range of the height of the pantograph;
- length of contact strips;
- maximum and minimum width of pantograph head;
- encroachment of the pantograph head above the contact point.

Parameters for interoperable pantographs are given in Table 3.

The maximum encroachment of the pantograph head shall be as set out in EN 15273-1:2013+A1:2016, 8.1.1.3 and shall not exceed 60 mm under all conditions.

NOTE 1 Typically the critical case is for a contact point at the end of the contact strips with maximum contact force applied.

For calculating the maximum lateral deviation of the contact wire for interoperable pantograph heads in accordance with 5.2.5, the working zone and point of dewirement are given in Figures A.6 and A.7.

NOTE 2 The point of dewirement is determined by the point where the gradient of the profile exceeds 40°. Until this point and with this gradient, experience indicates that the contact wire is able to return successfully into the working zone.

The design of the pantograph shall achieve performance in accordance with Clause 7 for the speed range and a contact wire height in accordance with 5.2.3. The reach of the pantograph shall not exceed 6,5 m above rail level.

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