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Introduction

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

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

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER: IEC 62486 ED3	
DATE OF CIRCULATION: 2024-12-13	CLOSING DATE FOR COMMENTS: 2025-03-07
SUPERSEDES DOCUMENTS: 9/3148/RR	

IEC TC 9 : ELECTRICAL EQUIPMENT AND SYSTEMS FOR RAILWAYS	
SECRETARIAT: France	SECRETARY: Mr Denis MIGLIANICO
OF INTEREST TO THE FOLLOWING COMMITTEES:	HORIZONTAL FUNCTION(S):
ASPECTS CONCERNED:	

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TITLE:

Railway applications – Current collection systems – Technical criteria for the interaction between pantograph and overhead contact line (to achieve free access)

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS – CURRENT COLLECTION SYSTEMS –
TECHNICAL CRITERIA FOR THE INTERACTION BETWEEN PANTOGRAPH
AND OVERHEAD CONTACTLINE (TO ACHIEVE FREE ACCESS)**

FOREWORD

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International Standard IEC 62486 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the upper line properties for both AC and DC power systems as well as the current collector characteristics have been clarified;
- b) the requirements for pantograph with individually spring parts of the pantograph head were taken;
- c) the lateral deviation of the contact wire is made in accordance with EN 15273;
- d) in Annex A have been added to specific conditions of CN and JP;
- e) in Annex B, special national conditions have been supplemented by the data of additional IEC members.

The text of this standard is based on the following documents:

FDIS	Report on voting
9/xxxx/FDIS	9/xxxx/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

This international standard is derived from the European standard EN 50367 that was offered to the IEC by CENELEC.

The reader's attention is drawn to the fact that Annexes B and C list all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this standard.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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RAILWAY APPLICATIONS – CURRENT COLLECTION SYSTEMS – TECHNICAL CRITERIA FOR THE INTERACTION BETWEEN PANTOGRAPH AND OVERHEAD CONTACTLINE (TO ACHIEVE FREE ACCESS)

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 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.

IEC 60050-811:2017+A1:2021, *International Electrotechnical Vocabulary – Chapter 811: Electric traction*

IEC 60494-1:2013, *Railway applications – Rolling stock – Pantographs – Characteristics and tests – Part 1: Pantographs for main line vehicles*

IEC 60913:2024, *Railway applications – Fixed installations – Electric traction overhead contact lines*

IEC 62313:2009, *Railway applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock*

IEC 62499:2021, *Railway applications – Current collection systems – Pantographs, testing methods for carbon contact strips*

IEC 62846:2016, *Railway applications – Current collection systems – Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line*

IEC 63453:2025, *Railway applications – Current collection systems – Validation of simulation of the dynamic interaction between pantograph and overhead contact line*

IEC 62917:2016, *Railway applications – Fixed installations – Electric traction – Copper and copper alloy grooved contact wires*

EN 15273:2017 (all parts), *Railway applications – Gauges*

3 Terms and definitions

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:

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

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

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: IEC 63453:20xx, 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 62846:2016, 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: IEC 63453:202x, 3.2, modified – The specific domain has been added in the definition]

3.6

contact wire height

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

Note 1 to entry: The contact wire height is measured perpendicular to the track or road 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]

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 15273-1:2017, 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**

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

[SOURCE: IEC 60913:2024, 3.1.5.8]

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: IEC 63453:202x, 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 15273-1:2017, Clause 3.

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]

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 or phase being connected together by the passage of current collectors

[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

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

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

contact loss

condition where the contact force is zero

Note 1 to entry: Contact loss surely induces arcing except in the case of coasting. However, if two or more pantographs are connected electrically each other, arc can disappear and then the condition will shift to current loss.

3.28

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]

3.29

Percentage of contact loss CtQ

proportion of driving time with contact loss, this is given by the following formula:

$$CtQ = \frac{\sum t_{ctl}}{t_{total}} \times 100$$

where

t_{ctl} is the duration of contact loss occurring in the simulation or measurement of contact force;

t_{total} is the simulation time or measuring time in total.

The result, given in %, is a characteristic for a given speed of the vehicle.

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)
$b'_{h,OC}$ L	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]
$b_{w,c}$	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]
$D_{I'o}$	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]
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
l'_o	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'_o	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]
Σ_j	sum of (horizontal) allowances for the structure gauge, covering certain random phenomena ($j = 1, 2$ or 3) [m]
ΣT_{Thref}	total of all tolerances of track at the reference height for interaction between contact wire and pantograph [m]
ΣT_o	total of all tolerances of track and overhead contact line at the upper verification point [m]
ΣT_u	total of all tolerances of track and overhead contact line at the lower verification point [m]
ΣT_{OCL}	total of all tolerances of overhead contact line [m]
ΣT_{To}	total of all tolerances of track at the upper verification point [m]
ΣT_{Tu}	total of all tolerances of track at the lower verification point [m]

195

196 **5 Geometry**197 **5.1 General**

198 This Clause provides requirements for geometric limits of pantographs preventing dewirement
199 and allowing for adequate interaction performance.

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

204 NOTE: The requirements in Clause 5 apply to standard gauge applications in accordance with EN 15273-1:2017,
205 EN 15273-2:2017 and EN 15273-3:2017. These requirements can be adapted to other track gauges.

206

207

208 **5.2 Overhead contact line characteristics**209 **5.2.1 General**

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

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

218 The overhead contact line shall conform to the requirements set out in IEC 60913:2024, 5.10.

219 **5.2.2 Infrastructure gauge for free passage of pantograph**

220 The design of the overhead contact line shall allow the operation of vehicles compliant to the
221 appropriate vehicle gauge for the route.

222 NOTE 1 This gauge is calculated in accordance with EN 15273-1:2017, EN 15273-2:2017 and EN 15273-3:2017. The
223 gauge for free and unrestricted passage of pantographs is calculated based on the kinematic gauge for pantographs
224 in accordance with EN 15273-3:2017, Clause 11.

225 Electrical clearances requirements shall be as set out in IEC 60913:2024, 5.1.3.

NOTE 2 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.

NOTE 3 The determination of the minimum height of structures above the contact line is in accordance with EN 15273-1:2017, 8.1.2.

For this, the encroachment of the pantograph head above the contact plane defined in 5.3.1, may be reduced by taking into consideration the maximum possible lateral position at this location.

NOTE 4 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 is 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 IEC 60913:2024, 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]	$v < 250$	$v \geq 250$
Range of nominal contact wire height [m]	from 5,0 up to 5,75	from 5,0 up to 5,3
Permissible gradient and change of gradient	in accordance with IEC 60913:2024, Table 12	in accordance with IEC 60913:2024, Table 12

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 requirements of 7.3 shall be replaced by the limits as set out in Table 4 of IEC60913:2024.

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.

For checking the stability against dewirement, the permissible lateral deviation of contact wire from track centre line (d_{Istab}) 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_{Iserv}) shall be calculated in accordance with 5.2.5.3.

NOTE 3 The permissible lateral deviations is calculated in accordance with EN 15273-1:2017, EN 15273-2:2017 and EN 15273-3:2017, considering the movements of pantographs and track gauge using the reference values set out in EN 15273-1:2017, Table G.1 and EN 15273-3:2017, 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_{Istab} (5.2.5.2)

— d_{Iserv} (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 4 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).

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

An example of calculation is given in informative Annex D.

For a visualization of lateral deviation see Annex 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:

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

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

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

303

NOTE 2 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 15273-1:2017, EN 15273-2:2017 and EN 15273-3:2017 for calculation of Σj .

NOTE 3 Possible index of j can be 1, 2 or 3 in accordance with EN 15273-3:2017, 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 4 Encroachment of pantograph head is not considered for this calculation.

NOTE 5 The value of f_s is dependent upon the overhead contact line design and is 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 6 With regard to probabilistic addition, see EN 15273-1:2017, Annex J.

The safety coefficient k' shall be chosen to achieve the required safety level, for which, a value of 1,0 is recommended.

NOTE 7 see EN 15273-3:2017, Table B.1.

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

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

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 8 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 $b'_{h,mec}$.

NOTE 1 $b'_{h,mec}$ is in accordance with EN 15273-1:2017, EN 15273-2:2017 and EN 15273-3:2017

The serviceability limit state is calculated as:

$$d_{lserv} = b_w + b_{w,c} - b'_{hOCL} = b_{w,c} - (e_{phref} + S'_{il a} + qS'_{il a}) \quad (5)$$

where

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

$$b'_{uOCL} = b_w + e_{pu} + S'_{il a} + qS'_{il a} \quad (7)$$

$$b'_{oOCL} = b_w + e_{po} + S'_{il a} + qS'_{il a} \quad (8)$$

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 Σ_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 IEC 60913:2024, 5.10.2.

5.2.7 Neutral sections

The electrical requirements for operation through neutral sections are set out in IEC 62313:2009, Clause 5. For the mechanical design, the following requirements of neutral sections shall be considered:

- the arrangement and structures shall allow trains to 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;
- 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.

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 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.

NOTE 1 The maximum encroachment of pantograph head is given in EN 15273-1:2017, 8.1.1.3 and is limited to maximum 60 mm under all conditions.

NOTE 2 Typically the critical case is with the contact point at the end of the contact strips with maximum contact forces 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 3 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 according to 5.2.3. The reach of the pantograph shall not exceed 6,5 m above rail level.

Table 3 – Pantograph characteristics for AC and DC systems

Profile of pantograph heads ^a	See Figure A.6 and Figure A.7
Maximum width of pantograph head (m) ^b	0,65
Minimum width of pantograph head (m) ^c	0,05
Mechanical kinematic pantograph gauge	see 5.2.2
^a See Figures B.1 to B.20 for the national profiles for existing lines. ^b Maximum width of pantograph head, [I] see A.1. ^c Minimum width applies for a pantograph with single contact strip	

NOTE 3 The reference point for the pantograph profiles refers to the contact point (of contact strip and contact wire) at the centre of the pantograph head.

The pantograph shall conform to the requirements as set out in IEC 60494-1:2013. Additional assessments are set out in 5.3.2.

5.3.2 Assessment of the pantograph head profile

5.3.2.1 General

Pantograph head profile assessment shall be undertaken on a new pantograph as set out below.

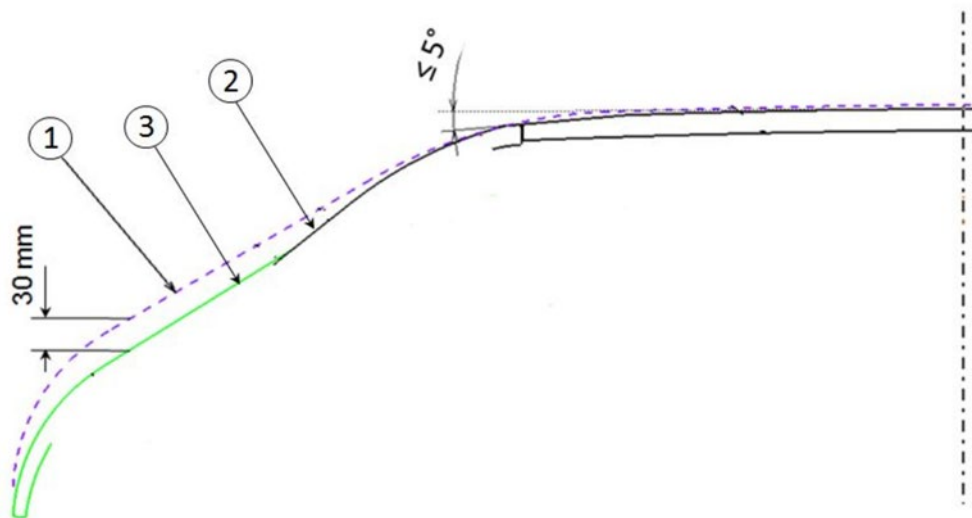
5.3.2.2 Continuous pantograph head profile (non-independently suspended contact strips)

Pantograph heads shall be compliant with the reference profile in accordance with Figures A.6 and A.7. Maximum vertical deviation from the reference pantograph profile is only allowed downwards and shall be less than 30 mm excluding the curved ends of the end horn.

Deviations below the pantograph profile at all positions inside the minimum collector strip length shall not exceed 5° (as shown in Figure 1) against the reference profiles as set out in A.2.

432

Dimension in millimetre



433

434

Key

435

1 reference pantograph profile

436

2 actual pantograph profile

437

3 maximum deviation from reference profile

438

439

Figure 1 — General detail of pantograph head with non-independently suspended contact strips

440

441

442

5.3.2.3 Non-continuous pantograph head profile (independently suspended collector strips)

443

444

The following assessments shall be undertaken in addition to the requirements set out in 5.3.2.2.

445

The transition between independently suspended parts of the pantograph head shall be checked.

446

447

In order to assess the non-continuous profile a static force of 70 N for AC and 90 N for DC shall be applied in the middle of the pantograph head.

448

449

For pantographs capable of operating with different static contact forces (such as multi voltage pantographs), the lowest value shall be used.

450

451

The location of the transition point between independently suspended parts of the pantograph head shall be within the transition zone as defined in Figure 2, key 1.

452

453

The following geometrical conditions shall be respected in the transition point:

454

— angle β between horizontal plane and end horn is between 0° and value given in Figures A.6 or A.7;

455

456

— angle α between horizontal plane and independently suspended part of pantograph head at the transition point is less or equal than 40° .

457

458

For the transition zone excluding the curved ends of the end horn of the pantograph head, a maximum vertical deviation of 40 mm downwards from the reference pantograph profile is allowed.

459

460

461

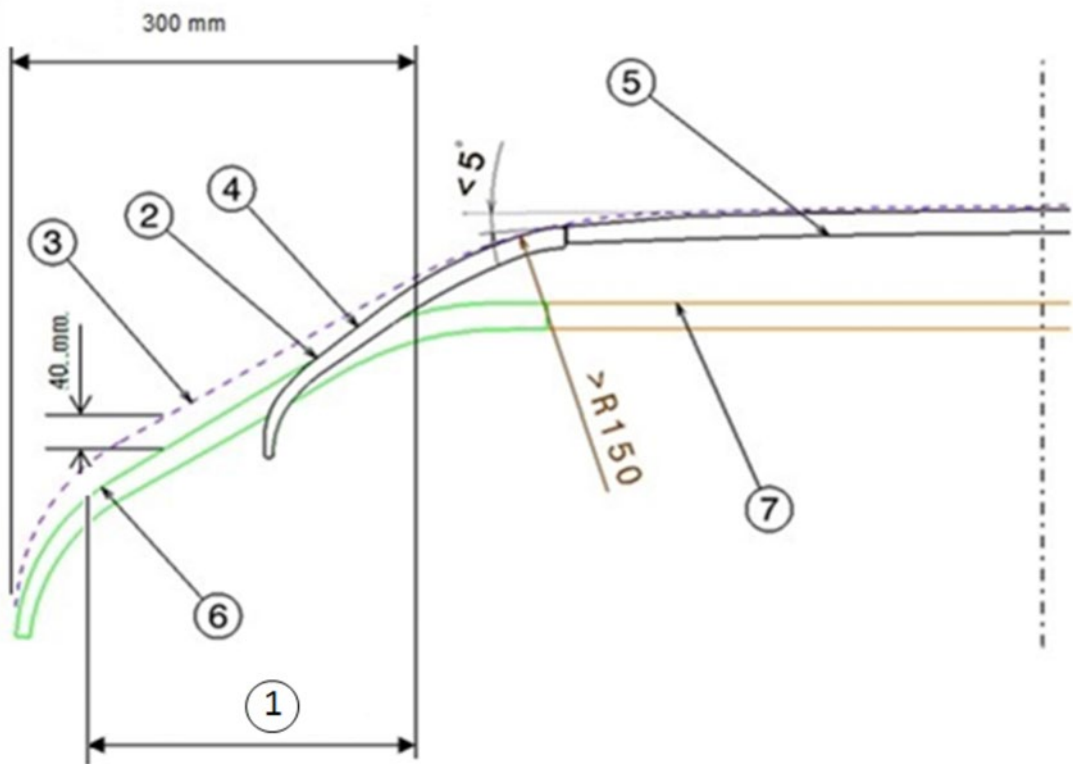
For the transition zone excluding the curved ends of the end horn of the pantograph head, a maximum vertical deviation of 40 mm downwards from the reference pantograph profile is allowed.

462

463

464

Dimension in millimetre



465

466

Key

- 1 transition zone
- 2 transition point
- 3 reference profile of pantograph head (see Figures A.6 and A.7)
- 4 end horn of contact strip
- 5 contact strip
- 6 end horn of pantograph head
- 7 non-independently suspended parts of the pantograph head

467

468

Figure 2 — General detail of pantograph head with independently suspended collector strip

469

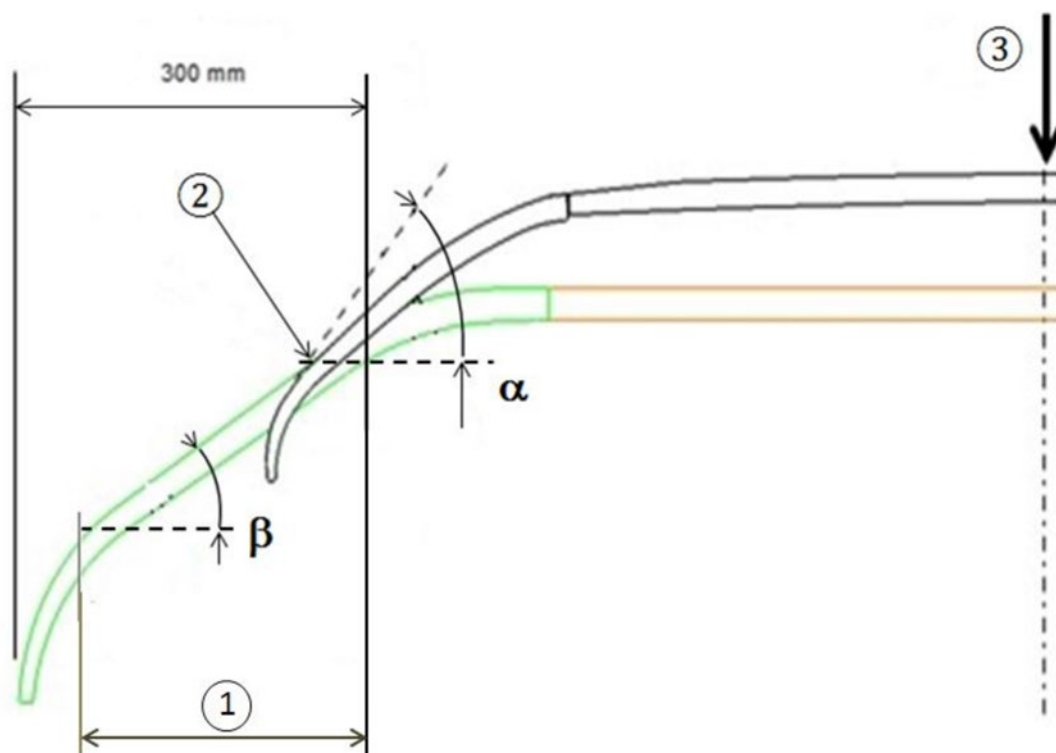
470

471

The position of transition point and the angle between the fixed and independent parts at the transition point shall be as defined in Figure 3.

472

Dimension in millimetre



473

474 **Key**

- 1 transition zone
- 2 transition point
- 3 static force

475 **Figure 3 — Transition point – 1 600 mm and 1 950 mm pantograph head**

476 The maximum value for α shall not exceed 40°. Maximum value for β is given by Figures A.6 or
477 A.7. The difference between the two angles shall be less than 10°.

478

479 **5.3.3 Conducting range**

480 The conducting range and the minimum length of contact strip shall be in accordance with
481 Figure A.6 and Figure A.7.

482 **6 Interface material**

483 **6.1 General**

484 The permissible current at the contact point depends significantly on the materials of the contact
485 wire and the contact strips, and the wear of the both components. In order to achieve a
486 satisfactory performance, the characteristics of contact wire and contact strips shall be in
487 accordance with 6.2 and 6.3 below.

488 **6.2 Contact wire**

489 The contact wire shall comply with the requirements of IEC 62917:2016: and shall be used in
490 accordance with IEC 60913:2024.