INTERNATIONAL UNION OF RAILWAYS

UIC CODE
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606-1

OR

1st edition, 1-1-87

CONSEQUENCES OF THE APPLICATION OF THE KINEMATIC GAUGES DEFINED BY UIC LEAFLETS IN THE 505 SERIES ON THE DESIGN OF THE CONTACT LINES (1)

(1) Obligatory provisions are preceded by an asterisk: *

REVISIONS

Leaflet 606-1, 1st edition of 1-1-1987			
Amendment		Amendment	
No.	Date	No.	Date
1	01.01.89		

This leaflet forms part of a series which also includes the following leaflets:

505-1 OI: Kinematic gauge for powered units used on international services

505-2 OI: Kinematic gauge for coaches and vans used on international services

505-3 ORI: Kinematic gauge for wagons used on international services

505-4 ORI: Effects of the application of the kinematic gauges defined in the 505 series of leaflets on the positioning of structures in relation to the tracks and of the tracks in relation to each other

505-5 OI: Basic conditions common to Leaflets Nos. 505-1 to 505-4. Notes on the preparation and provisions of these leaflets.

506 OR: Rules for the application of the enlarged gauges CA, GB and GC

600 OR: Electric traction with aerial contact line

606-2 OR: Installation of overhead contact lines for electric traction systems at 25 kV, 50 or 60 Hz

608 R: Conditions to be complied with for the pantographs of tractive units used on international services

CONTENTS

0 - GENERAL

0.1 Purpose of the leaflet

This leaflet gives rules for electrical units in international service. It contains methods of calculation for relative movement between the pantograph and the catenary. Provisions and recommendations for the catenary can be derived from these, provided the tractive units comply with Leaflet 505-1, and that the movement of the units connected with the track bed is calculated in accordance with Leaflet 505-4.

0.2 Scope

This leaflet describes the relative horizontal and vertical movement of the contact wire and the pantograph, also the necessary clearance for the passage of the catenary.

UIC Leaflet 505-1 gives the provisions which tractive units and their pantographs must meet.

UIC Leaflet 505-4 gives the width of the structure gauge in the pantograph zone.

The methods of calculation and the values indicated in this leaflet should be used when there are no national provisions to the contrary.

0.3 Symbols

A	sum of the diameters of the contact wire and the catenary
α'	angle between sloping part of bow and horizontal (see Appendix 4)
a	distance between pivots
a_s	length of registration arm
b'	electrical distance
b_1	clearance between plane electrodes for normal atmospheric pressure (including variations in the humidity of air)
b_2	allowance for atmospheric pressure variations
b_3	allowance for pollution
b_4	allowance for unequal distribution of the field
b_5	allowance for over-voltages appearing in the overhead line network
b_6	other allowances
b_w	half-width of bow (see Appendix 4)
c	span
d	external distance between flanges at limit of wear (see Appendix 2) (generally 1.410 m)
d_e	distance between points supporting wheels (see Appendix 2) (generally 1.500 m)
ϵ	coefficient of drag of the wires, cables and droppers
E	cant excess
E_o	portion of the cant excess included in the reference outline in the field of the body of the vehicle (0.050 m)
E'_o	portion of the cant excess included in the reference outline in the pantograph zone (0.066 m)
e_p	off-centre of the pantograph due to the characteristics of the vehicle as per Leaflet 505-4 (revised version)
e_{po}	e_p at the height of the upper verification point (0.150 m)
e_{pu}	e_p at the height of the lower verification point (0.110 m)
η_3	angle of oscillation of the vehicle (values as per Leaflet 505-4, page 33)
F	horizontal component of the working force of the pantograph
f	deflection of the track
f_{do}	upwards dynamic oscillations of the contact wire

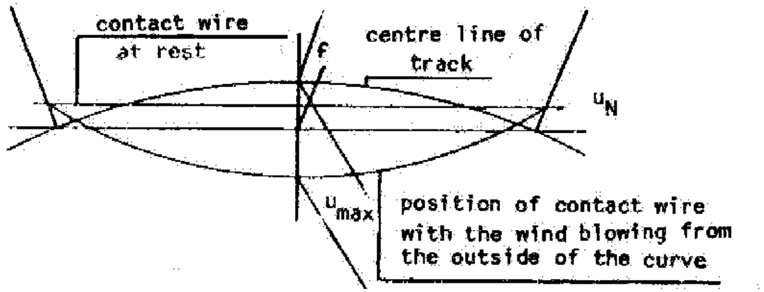
f_{du}	downwards dynamic oscillations of the contact wire
f_e	effects of ice on the height of the contact plane
f_f	upwards deviation of the contact plane due to wear of the contact wire
f_g	allowance to cater for raising of the track during maintenance
f_L	sum of the offset and displacements of the contact wire
f_{mo}	upwards deviation of the tolerance for fitting of the contact wire
f_{mu}	downwards deviation of the tolerance for fitting of the contact wire
f_q	quasi-static lifting of the contact wire at maximum speed (additional to f_s)
f_s	static uplift of the contact wire by the pantograph
f_{to}	uplift of the contact wire at the lowest temperature, measured in relation to its position for the average temperature
f_{tu}	sag of the contact wire at the highest temperature, measured in relation to its position for the average temperature
f_{wa}	encroachment of the bow beyond the contact plane because of wear of the carbon (see Appendix 5)
f_{ws}	encroachment of the bow beyond the contact plane because of an inclined position (see Appendix 5)
f_v	sag of the contact wire. Initial sag including sag between droppers
g	acceleration due to gravity ($9.81\ m/s^2$)
γ	specific weight of the air ($11.5\ N/m^3$)
h	height considered
h_c	height of the roll centre of specific vehicle
h_{co}	height of the roll centre of reference vehicle (0.50 m)
h_{fmax}	maximum height of the contact wire
h_{fmin}	minimum height of the contact wire
h_{fn}	nominal height of the contact wire
$h_{fn\ max}$	maximum nominal height of the contact wire at the support
hfn_{min}	minimum nominal height of the contact wire at the support
h_L	height of the limiting structure gauge as per Leaflet 505-4
h'_L	height of the limiting structure gauge in the zone of the pantograph as per Leaflet 505-4 (function of h_{fmax})
h_{LFd}	height corresponding to the highest position of the pantograph
h'_o	height of the upper verification point (6.5 m)
h_R	height of corresponding point of the reference outline
$h_{sa\ max}$	maximum working height of pantograph
h_t	height of the lower articulation of the pantograph

h'_u	height of the lower verification point (5.0 m)
I	cant deficiency
I_o	part of the cant deficiency included in the reference outline in the field of the body of the vehicle (0.050 m)
I'_o	part of the cant deficiency included in the reference outline in the field of the pantograph (0.066 m)
k	actual plan working force
l	track gauge (see Appendix 2)
l_{max}	maximum track gauge (generally 1.470 m)
l_n	nominal track gauge (generally 1.435 m)
Δl_f	longitudinal expansion (half-movement) of the contact wire
n	distance of cross-section from nearest pivot or outer axle
n_f	distance from the fixed point
p	wheelbase of bogie
q	play between axle and bogie
q_w	dynamic wind pressure on the wire
Q_i/Q_a	quasi-static inward-outward inclination
R	curve radius
s	coefficient of slope/tilt for the vehicle considered
s_o	conventional value for coefficient of slope/tilt for passenger coaches (0.400)
s'_o	conventional value for coefficient of slope/tilt of vehicles with pantographs (0.225)
S_i/S_a	overhang inwards/outwards
T	movement due to random phenomena
T_1	transverse movement of the track between two overhauls (generally 0.025 m)
T_{2g}/T_{2d}	movement due to cant defects, geometrical portion/quasi-static portion (dynamic portion as per leaflets in the 505 series)
T_{3i}/T_{3a}	movement due to oscillation (inwards/outwards)

T_4	movement due to non-symmetrical characteristics of vehicles not included in the reference outline
T_5	movement due to unevenly distributed loads
t	coefficient of flexibility of the pantograph
t_2	cant tolerance (generally 0.015 m)
τ	tolerance of the pantograph
θ	adjustment tolerance of the vehicle suspension
Δt	difference in temperature considered in °C (generally 100°C)
u_a	side movement of the contact wire as a result of longitudinal movement of the bracket or of registration arm
u_d	side movement of the contact wire due to wind in relation to position at rest
u'_d	side movement of the contact wire in alignment due to wind in relation to the track centre
u_m	side movement of the contact wire due to movement of the mast
u_{max}	maximum off-set of the contact wire in the span
u_N	absolute value of nominal off-set of the contact wire at support
u_{N1}, u_{N2}	absolute value of nominal off-set of the contact wire at support for 2 consecutive supports
u_p	movement of the contact wire under the influence of the horizontal component of the working force of the pantograph
u_t	off-set of the contact wire because of construction tolerances
v	maximum wind speed to be taken into consideration
w	play between bogie and vehicle body
w_a	play between bogie and vehicle body on outer curve
w_i	play between bogie and vehicle body on inner curve
w_s	half-width of the contact strip (see Appendix 4)
$w_ü$	residual bow width
$w_{üa}$	allowable residual bow width (see Appendix 4)
$w_{üFF}$	residual bow width in the span with moving vehicle
$w_{üFS}$	residual bow width in the span, with stationary vehicle
$w_{üSt}$	residual bow width at the support
w_w	half-width of the working zone of the bow (see Appendix 4)
Z_f	sum of the mechanical tensions of the contact wire and the catenary
Z_{fd}	mechanical tension of the contact wire

0.4 Definitions:

Maximum off-set of the contact wire in the span u_{max}:
Limiting value for the sum of the off-set level with the support, the deflection of the track and blow-off which are basic data for the design of the catenary system.



Residual bow width $w_ü$:
Horizontal distance between the contact wire and the end of the bow.

Allowable residual width $w_{üa}$:
Residual width allowing for reliable operation and which must be complied with even for extreme positions of the contact wire and the bow.

Sag of the contact wire f_v:
Initial sag including sag between droppers.

1 - HORIZONTAL MOVEMENT OF CONTACT WIRE RELATIVE TO PANTOGRAPH

1.1 Principles

1.1.1 Relative movement

Under the environmental conditions defined, the horizontal movement of the contact wire and of the pantograph must never be such that the contact wire can slide off the bow. The end of the bow must always exceed the extreme position of the contact wire by a certain value. This value

will be described in the remainder of the text by the term "residual bow width ($w_ü$)".

Even for positive values of the residual width, troublefree functioning is not guaranteed if the registration points (parts fixed to the contact wire) come into contact with the inclined horns of the bow. To ensure troublefree functioning, the contact wire must not leave the working width $2w_w$ of the bow, and must normally remain within the width $2w_s$ of the contact strips (see Appendix 4).

The outline described in Leaflet 505-1 [1)] shown in Appendix 1 of this leaflet, indicates the movement of the bow which should be adopted when designing the catenary system.

*1.1.2 Vehicles

Compliance with Leaflet 505-1 [1)] ensures with acceptable probability that the movement of the bow remains within the zone of the "off-set of the central point of the bow e_p" shown in Appendix 1. The catenary system shall be designed on the basis of this zone of movement of the bow. In this way, the catenary system can be designed independently of the vehicle.

*1.1.3 Catenary and allowable residual bow width

The span, nominal off-set of the contact wire, the mechanical tension of the contact wire, the horizontal movement of the registration arm following longitudinal movement of the catenary, and the rigidity on deflection of the masts must be chosen in relation to the deflection of the track, so that the residual bow width $w_ü$ is not less than a given value $w_{üa}$.

The allowable residual width $w_{üa}$ shall be fixed by the administration to which the railway belongs.

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1) According to the conclusions of the meeting of Working Parties 57/A and 7/H on 29 January 1965 in Paris, the pantograph must also be verified at a height of 5.0 m. Leaflet 505-1 will be completed accordingly.

1.1.4 Residual bow width

The residual bow width $w_{ü}$ is determined from the half-width of the bow b_w from which must be subtracted:

- the off-set of the pantograph e_p due to the vehicle as per Leaflet 505-1 1)
- the movements of the vehicle connected with the track bed as per Leaflet 505-4, also
- the off-set and movement of the contact wire f_L as per this leaflet.

*1.1.5 Horizontal movement of the contact wire

The following factors must be considered when calculating the horizontal movement of the contact wire:

- the off-set at the support, the span in relation to the curve radius and the blow-off. Note: Several railways choose these three variables so that the off-set in the span does not exceed a limiting value u_{max}.
- the horizontal deflection movement of the masts as a result
  - of movement of the foundation
  - of the load exerted by fixed supports, cables and wires
  - statically
  - when this load is modified due to
    - temperature variations,
    - the fitting or dismantling of components (e.g. supply conductors)
  - of wind blowing in the direction relative to the track.
    Note: The movements of the foundation and the variations in load due to the fitting or

1) According to the conclusions of the meeting of Working Parties 57/A and 7/H on 29 January 1985 in Paris, the pantograph must also be verified at a height of 5.0 m. Leaflet 505-1 will be completed accordingly.

dismantling of components are generally compensated for by adjustment of the off-set, so that there it is only necessary to take into account chance movement produced by wind and by variations in the tensile stress in the conductors fixed to the support.

- Installation tolerances

  Note: These tolerances include not only the inaccuracies of installation, but also the deviations resulting from the fact that it is not possible continuously to adjust certain components (e.g. registration arms which can only be adjusted periodically).

- Longitudinal movement of the registration drop bracket and of the registration arm

  Note: The registration drop bracket and the registration arm follow the longitudinal movements Δl_f of the conductors, which brings about a lateral movement of the contact wire. The extent of this movement depends on the distance of the support in question from the fixed point, also on temperature variations. The range of temperatures Δt is defined by the adjustment of the tensioning equipment or by the lowest local temperature and the highest electrical heating temperature of the contact wire which it is decided to permit when the local temperature is at its highest.

- The lateral component of the working force of the pantograph

  Note: As soon as the contact wire is positioned on the inclined part of the bow, a component F of the pantograph working force k is exerted laterally on the contact wire. This moves the contact wire transversely, reducing the residual width still further.

*1.2 Basic data

1.2.1 Basis for measurements

The off-set of the contact wire is measured in relation to the perpendicular to the running surface, passing through a point equidistant from the two rails.

1.2.2 Cases to be considered

When designing the components of the catenary system which have an influence on the transverse position of the contact wire, it is necessary to consider the following three cases:

- at the support in the case of a stationary vehicle on a cant
- in the span with maximum force wind from the outside of the curve and at maximum speed of the vehicle
- in the span with maximum force wind from the inside of the curve and when the vehicle is stationary.

In these three cases, the residual bow width $w_{ü}$ must remain sufficient, namely not less than $w_{üa}$.

Note: It should be noted that the maximum off-set u_{max} of the contact wire does not occur at mid-span if there are differing off-sets at the two adjacent points of support.

1.3 Method of calculation

1.3.1 Span

The relationship between curve radius, off-set and blow-off is as follows:

$$c = \sqrt{8R \cdot Z_f \cdot (u_N + u_{max}) / (q_w \cdot e \cdot A \cdot R + Z_f)} \text{ where}$$

- c = span (m)
- R = curve radius (m)
- Z_f = sum of the mechanical tensions of the wire and of the catenary (N)
- u_N = the nominal offset of the contact wire (m) at the support point
- u_{max} = maximum offset of the contact wire in the span (m)
- q_w = $\gamma v^2/2g$ dynamic pressure of wind on the wire (N/m²)
- γ = 11.5 N/m³ = specific weight of the air
- g = 9.81 m/s² = acceleration due to gravity
- v = maximum wind speed (m/s)
- e = 1.25 = coefficient of drag of the wires, cables and droppers
- A = sum of the diameters of the contact wire and of the catenary (m)

The displacement under the action of wind u_d can be calculated as follows:

$$u_d = \frac{q_w \, e.A.c^2}{8 \, Z_f} \text{ (m)}$$

Taking into account the different off-set at the supports on either side, on straight track the sum of blow-off due to wind and off-set is calculated as follows:

$$u'_d = u_d + \frac{(u_{N1} + u_{N2})^2}{16 \, u_d} + \frac{(u_{N1} - u_{N2})}{2} \text{ (m)}$$

The span thus calculated is the maximum value. Other reasons (e.g. a reduced encumberance at overhead structures) will require a smaller value.

1.3.2 Longitudinal movement of the registration drop bracket and of the registration arm.

The lateral movement u_a of the contact wire as a result of its variations in length due to changes in temperature is determined by the length a_s of the registration arm, by means of the following formula

$$u_a = \Delta l_f^2 / 2a_s \quad \text{(m) where:}$$

- Δl_f = $17.10^{-6}.n_f.\Delta t/2$ (m) = half-value of the longitudinal movement of the contact wire
- n_f = distance from the fixed point (m)
- Δt = temperature range considered, in °C

on the understanding that at average temperature the registration drop bracket or the registration arm is perpendicular to the track.

According to the type of support point, account should also be taken of the movement of the cantilever.

1.3.3 Horizontal component of the pantograph working pressure

The lateral movement of the contact wire due to the horizontal component of the pantograph working pressure over the sloping part of the bow amounts:

$$u_P = \frac{c.F}{4Z_{fd}} = \frac{c.K.tg\,\alpha'}{4Z_{fd}} \quad (m)$$

K = working force of the pantograph (N)

F = horizontal component (N)

α' = sloping part of pan in relation to the horizontal (°)

c = span (m)

Z_{fd} = mechanical tension of the contact wire (N).

Generally speaking, the force F is only important when the contact wire is situated on the pan horn namely outside the usable width.

*1.3.4 Calculation of the residual bow width

The movement of the vehicle and of the contact wire in relationship to the width of the pan are important. Only a method of calculation taking into account the probability of the simultaneous intervention of chance movements will make it possible to define allowable residual bow widths. In accordance with the method defined in UIC Leaflet 505-5, Appendix F, and the above formulae, the residual bow width $w_{\ddot{u}}$ will be calculated as follows:

Opposite the support, with the vehicle stationary:

$$w_{\ddot{U}St} = b_w - e_p - u_N - \frac{2.5}{R} - \frac{(l-l_n)}{2} - \frac{s_o'(h-h_{co})}{d_e}(E-E_o') - \sqrt{T_1^2 + \frac{t_2^2[h(1+s_o')-s_o'.h_{co}]^2}{d_e^2} + [(h-h_{co})tg\,\eta_{31}]^2 + u_m^2 + u_t^2 + u_a^2}$$

In the span with maximum force wind from the outside of the curve and at maximum speed of the vehicle:

$$w_{\ddot{U}FF} = b_w - e_p + u_N - \frac{c^2}{8R} - u_p - \frac{2.5}{R} - \frac{(l-l_n)}{2} - \frac{s_o'(h-h_{co})}{d_e}(l-l_o') - \sqrt{T_1^2 + \frac{t_2^2[h(1+s_o')-s_o'.h_{co}]^2}{d_e^2} + [(h-h_{co})tg\,\eta_{3d}]^2 + u_m^2 + u_t^2 + u_a^2 + u_d^2}$$

In the span with wind from the inside of the curve and with the vehicle stationary:

$$w_{\ddot{U}FS} = b_w - e_p - u_N + \frac{c^2}{8R} - u_p - \frac{2.5}{R} - \frac{(l-l_n)}{2} - \frac{s_o'(h-h_{co})}{d_e}(E-E_o') - \sqrt{T_1^2 + \frac{t_2^2[h(1+s_o')-s_o'.h_{co}]^2}{d_e^2} + [(h-h_{co})tg\,\eta_{31}]^2 + u_m^2 + u_t^2 + u_a^2 + u_d^2}$$

Where:

$$e_p = e_p(h) = e_{pu} + \frac{(h-h_u')}{(h_o'-h_u')}(e_{po}-e_{pu}).$$

2 - HEIGHT OF THE CONTACT WIRE

2.1 Principles

The nominal height of the contact wire h_{fn} must be chosen so that, either the wire does not go below the minimum height h_{fnmin} or it does not exceed the maximum working height of the pantograph h_{samax}.

The minimum height h_{fmin} is given either by national regulations or by the need to avoid arcing between the contact wire and the vehicles.

The minimum nominal height at the support h_{fnmin} is calculated by adding to the minimum height h_{fmin} all the movements of the contact wire downwards.

The maximum height h_{fmax} is limited by the maximum working height of the pantograph, by structures or by regulations.

The maximum nominal height h_{fnmax} at the support results from the maximum working height of the pantograph h_{samax} from which must be subtracted the uplift of the contact wire.

2.2 Basic data

*2.2.1 The height of the contact wire above the rails is measured along a perpendicular to the running surface. The height is measured in relation to the design position of the track.

*2.2.2 Minimum height of the contact wire h_{fmin}

Unless otherwise prescribed in national regulations, the height of the contact wire must never be less than the height h_L of the limiting gauge of the high parts of vehicles as per Leaflet 505-4, increased by the electrical distance b'.

b' consists of the following elements:

- b_1 clearance between plane electrodes for normal atmospheric pressure (including variations in air humidity),
- b_2 allowance for pressure variations,
- b_3 allowancefor pollution (running of thermal units, proximity to the sea, industrial pollution),
- b_4 allowance for unequal distribution of electrical field,
- b_5 allowance for over-voltages appearing in the catenary network,
- b_6 other safety allowances (birds, operating irregularities).

b_4 to b_6 can be regarded as random phenomena. The values of b_1 to b_6 for the various current systems are given in Appendix 6. The values indicated are to be considered as minimum distances unless local conditions allow them to be reduced.

*2.2.3 Minimum nominal height at the support $h_{fn\ min}$

The smallest nominal height at the support is calculated from the minimum height of the contact wire, to which must be added:

- f_v sag of contact wire: preliminary sag and sag between droppers
- f_{mu} downwards deviation of the tolerance for fitting of the contact wire
- f_{du} downwards dynamic oscillations of the contact wire
- f_g levelling tolerances of the track
- f_e effects of ice on the height of the contact plane, or
- f_{tu} sag of the contact wire at the highest temperature, measured in relation to its position for the average temperature.

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1) This breakdown of the electrical clearances makes it possible to explain uniformly the electrical clearances adopted by the various administrations and the distances laid down in IEC Leaflet CT9.

f_{mu} and f_{du} occur at random.
f_{tu} only occurs if the catenary is not automatically tensioned.
f_v and f_g must only be taken into account if they actually exist.

Bearing in mind the probability of the simultaneous occurrence of random factors, the minimum nominal height at the support will be determined by the following formula:

$$h_{fn\ min} = h_L + b_1 + b_2 + b_3 + f_g + \left(\begin{matrix} f_e \\ or \\ f_{tu} \end{matrix}\right) + f_v + \sqrt{b_4^2 + b_5^2 + b_6^2 + f_{mu}^2 + f_{du}^2}$$

2.2.4 Nominal height h_{fn} of the contact wire

For a certain section, the nominal height of the contact wire h_{fn} can be chosen freely between the minimum nominal height $h_{fn\ min}$ and the maximum nominal height $h_{fn\ max}$ (see 2.2.6):

$$h_{fn\ min} \leqslant h_{fn} \leqslant h_{fn\ max}$$

*2.2.5 Maximum height of the contact wire $h_{f\ max}$

The maximum height $h_{f\ max}$ of the contact wire results from the nominal height of the contact wire h_{fn} to which the following elements must be added:

- f_s static uplift of the contact wire by the pantograph
- f_q additional quasi-static uplift of the contact wire at maximum speed
- f_{do} upward dynamic oscillations of the contact wire
- f_{to} uplift of the contact wire at the lowest temperature, measured in relation to its position for the average temperature
- f_{mo} upwards deviation of the tolerance for fitting of the contact wire

f_{do} and f_{mo} are random.

Bearing in mind the probability of the simultaneous occurrence of the random factors, the maximum height of the contact wire will be determined by the following formula:

$$h_{fmax} = h_{fn} + f_s + f_q + f_{to} + \sqrt{f_{do}^2 + f_{mo}^2}$$

*2.2.6 Maximum nominal height at the support $h_{fn\ max}$

The maximum nominal height at the support is obtained by deducting from the maximum working height of the pantograph $h_{sa\ max}$ the possible movements of the contact wire upwards, namely f_s, f_q, f_{do}, f_{to}, and f_{mo}.

To avoid the contact wire exceeding the maximum working height of the pantograph, the maximum nominal height is calculated algebraically:

$$h_{fn,max} = h_{sa\ max} - f_s - f_q - f_{do} - f_{to} + f_{mo}$$

*2.2.7 Height corresponding to maximum movement in the pantograph h_{LFd}

The height h_{LFd} corresponding to maximum movement in the pantograph comprises the maximum height of the contact wire h_{fmax} increased by the following values (see Appendix 5):

- f_f deviation upwards of the contact plane due to wear of the contact wire (reduction in weight and diameter),
- f_{wa} encroachment of the bow beyond the contact plane because of wear,
- f_{ws} encroachment of the bow beyond the contact plane because of an inclined position.

$$h_{LFd} = h_{fn} + f_s + f_q + f_{to} + f_f + f_{wa} + \sqrt{f_{do}^2 + f_{mo}^2 + f_{ws}^2}$$

*2.2.8 Height of the limiting structure gauge in the pantograph zone h'_L

The height h'_L of the limiting structure gauge in the zone of the pantograph is determined by adding the electrical clearance b' and any other allowances to the height h_{LFd}.

$$h'_L = h_{fn}+f_s+f_q+f_{to}+f_f+f_{wa}+b_1+b_2+b_3+\sqrt{f_{do}^2+f_{mo}^2+f_{ws}^2+b_4^2+b_5^2+b_6^2}$$

3 - SPACE FOR THE CONTACT LINE

*3.1 Catenary

It is necessary to reserve the necessary space for the catenary.

To determine the upper limit, the basis used should be the nominal height of the contact wire corresponding to the point in question. To this it is necessary to add the overall dimensions at the support (encumberance).

Laterally, the values indicated in Section 1, also the electrical distance b', must be taken into account for the contact wire, and in the same way, for the catenary. Appendix 3 gives an example of the space necessary for the longitudinal structure of the catenary.

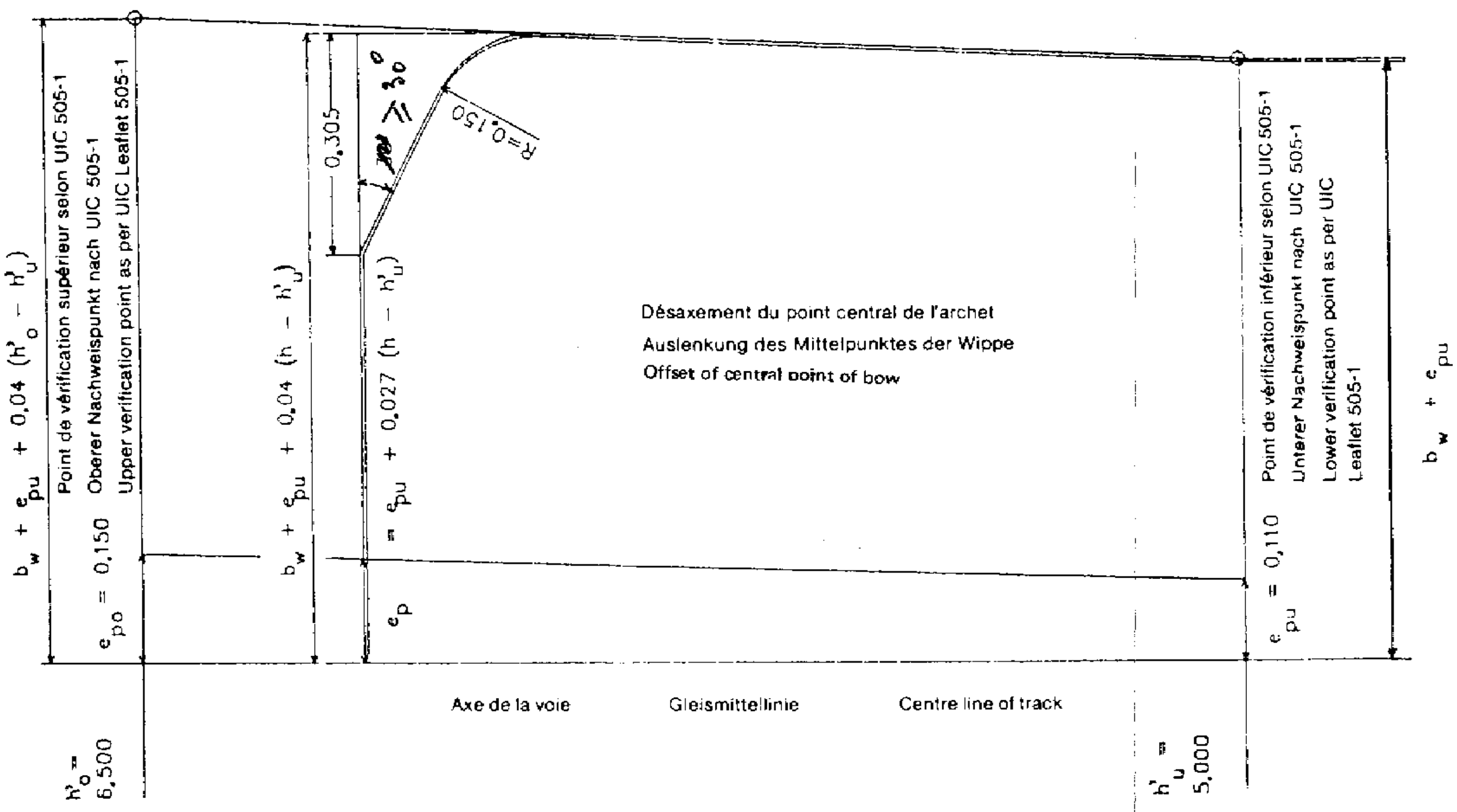
*3.2 Other parts of the contact line

Additional space must be provided in the following cases:

- level with the supports,
- where there are points and crossings,
- at tensioning and sectioning equipment, and at points where section insulators have to be installed,
- level with supply connections,
- existence of feeders and supply lines.

Its dimensions depend on the type of catenary used on the section in question.

CONTOUR DE RÉFÉRENCE POUR LE PANTOGRAPHE - BEZUGSLINIE FUER DEN STROMABNEHMERBEREICH - REFERENCE OUTLINE FOR PANTOGRAPH



The calculation of relative movement between the contact wire and the bow is based on the movement of the bow as a result of the characteristics of the vehicle e_p. This latter is calculated as per the following formulae: Vehicles built as per Leaflet 505-1 comply with the limits given by the following inequalities:

1 - PANTOGRAPH SITUATED BETWEEN THE AXLES OR PIVOTS

1.1 Vehicles with $an - n^2 + (p^2/4) \leqslant 5$

At a height $h = h'_o = 6.5$ m:

$$e_p = q + w_t + (h'_o - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_o - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_o - h_c)]^2} - 0.005 \leqslant e_{po} = 0.150 \text{ m}$$

At a height $h = h'_u = 5.0$ m:

$$e_p = q + w_t + (h'_u - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_u - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_u - h_c)]^2} - 0.020 \leqslant e_{pu} = 0.110 \text{ m}$$

1.2 Vehicles with $an - n^2 + (p^2/4) > 5$

At a height $h = h'_o = 6.5$ m:

$$e_p = [an - n^2 + (p^2/4) - 5]/300 + q + w_t + (h'_o - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_o - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_o - h_c)]^2} - 0.005 \leqslant e_{po} = 0.150 \text{ m}$$

At a height $h = h'_u = 5.0$ m:

$$e_p = [an - n^2 + (p^2/4) - 5]/300 + q + w_t + (h'_u - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_u - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_u - h_c)]^2} - 0.020 \leqslant e_{pu} = 0.110 \text{ m}$$

APPENDIX 1

2 - PANTOGRAPH SITUATED BEYOND THE END AXLES OR PIVOTS

2.1 Vehicle with $an + n^2 - (p^2/4) \leqslant 5$

At a height $h = h'_o = 6.5$ m:

$$e_p = (l_{max} - d) \cdot n/a + q(2n+a)/a + w_a(n+a)/a + w_t \cdot n/a + (h'_o - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_o - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_o - h_c)]^2} - 0.005 \leqslant e_{po} = 0.150 \text{ m}$$

At a height $h = h'_u = 5.0$ m:

$$e_p = (l_{max} - d) \cdot n/a + q(2n+a)/a + w_a(n+a)/a + w_t \cdot n/a + (h'_u - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_u - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_u - h_c)]^2} - 0.020 \leqslant e_{pu} = 0.110 \text{ m}$$

2.2 Vehicle with $an + n^2 - (p^2/4) > 5$

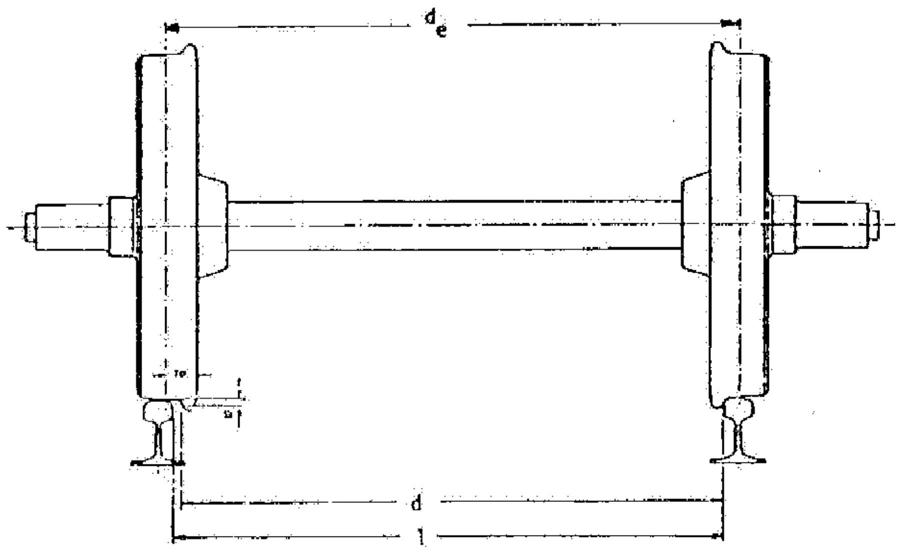
At a height $h = h'_o = 6.5$ m:

$$e_p = [an + n^2 - (p^2/4) - 5]/300 + (l_{max} - d) \cdot n/a + q(2n+a)/a + w_a(n+a)/a + w_t \cdot n/a + (h'_o - h_c) \cdot I'_o \cdot s/d_e + \sqrt{[t(h'_o - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_o - h_c)]^2} - 0.005 \leqslant e_{po} = 0.150 \text{ m}$$

At a height $h = h'_u = 5.0$ m:

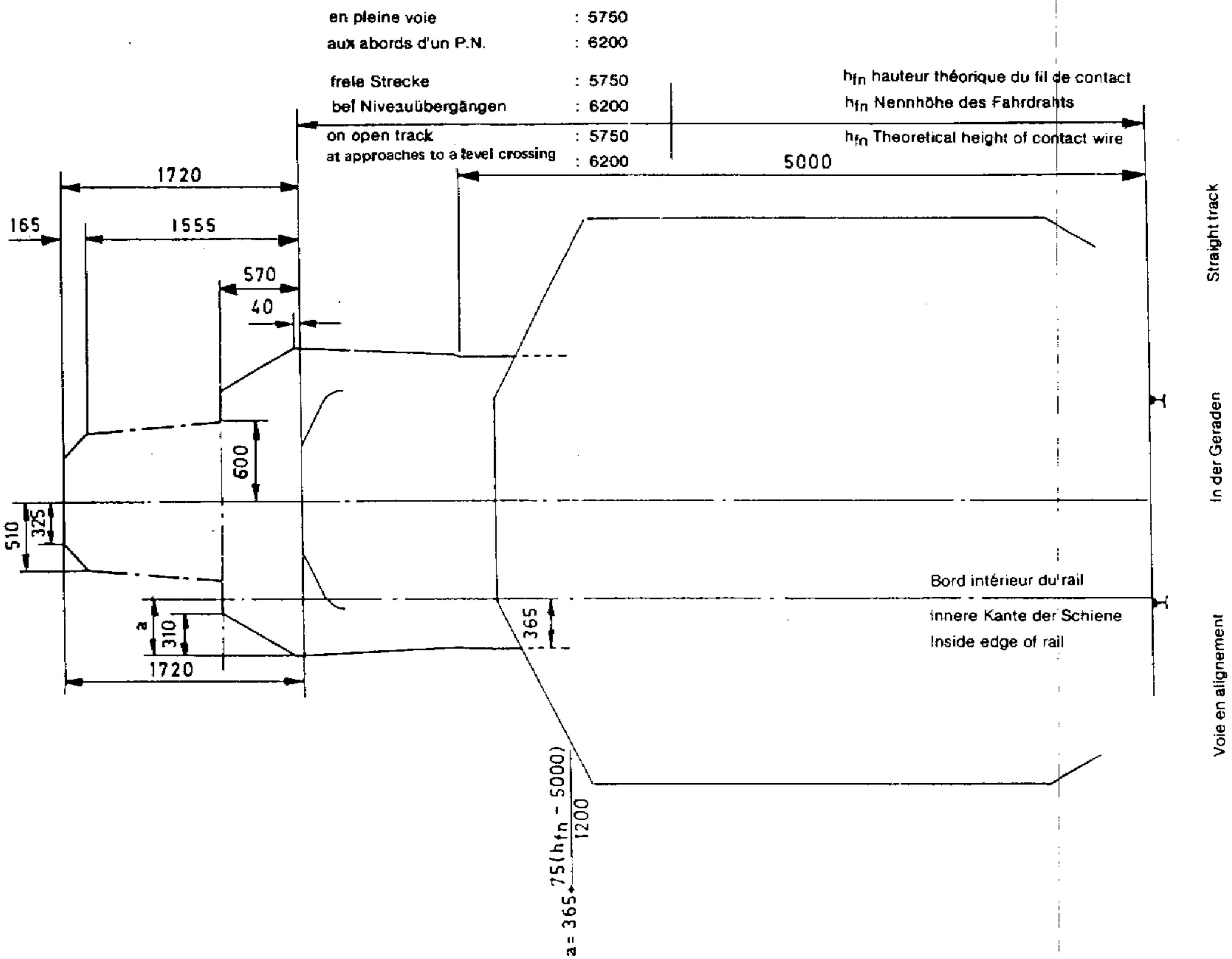
$$e_p = [an + n^2 - (p^2/4) - 5]/300 + (l_{max} - d) \cdot n/a + q(2n+a)/a + w_a(n+a)/a + w_t \cdot n/a + (h'_u - h_c) \cdot I'_c \cdot s/d_e + \sqrt{[t(h'_u - ht)/(6.5 - ht)]^2 + \tau + [\theta(h'_u - h_c)]^2} - 0.020 \leqslant e_{pu} = 0.110 \text{ m}$$

ECARTEMENT DES ROUES ET DE LA VOIE
SPURMASS DES RADSATZES UND SPURWEITE DES GLEISES
DISTANCE BETWEEN WHEELS AND TRACK GAUGE



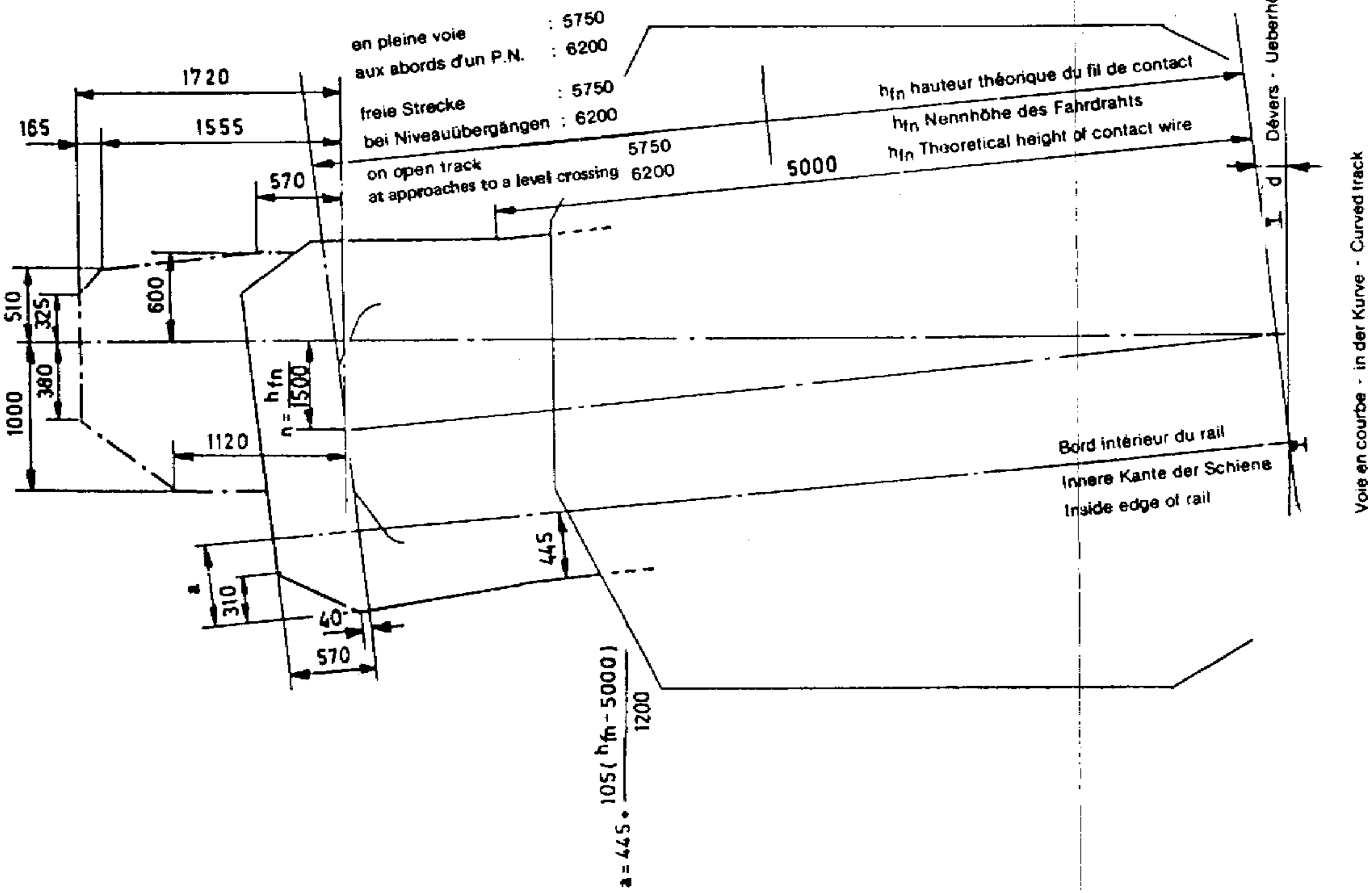
Ecartement des boudins à la limite d'usure Spurmass des abgenutzten Radsatzes Distance apart of flanges at limit of wear	d
Distance entre les points d'appui des roues Abstand der Messkreise der Räder Distance between supporting points of wheels	d_e
Ecartement de la voie Spurweite des Gleises Track gauge	1

ESPACE POUR LA STRUCTURE LONGITUDINALE DE LA CATENAIRE 25 kV, 50Hz Exemple de la SNCF
RAUM FUER DAS LAENGSKETTENWERK 25 kV, 50 Hz Am Beispiel der SNCF
SPACE FOR LONGITUDINAL STRUCTURE OF CATENARY 25 kV, 50 Hz SNCF Example

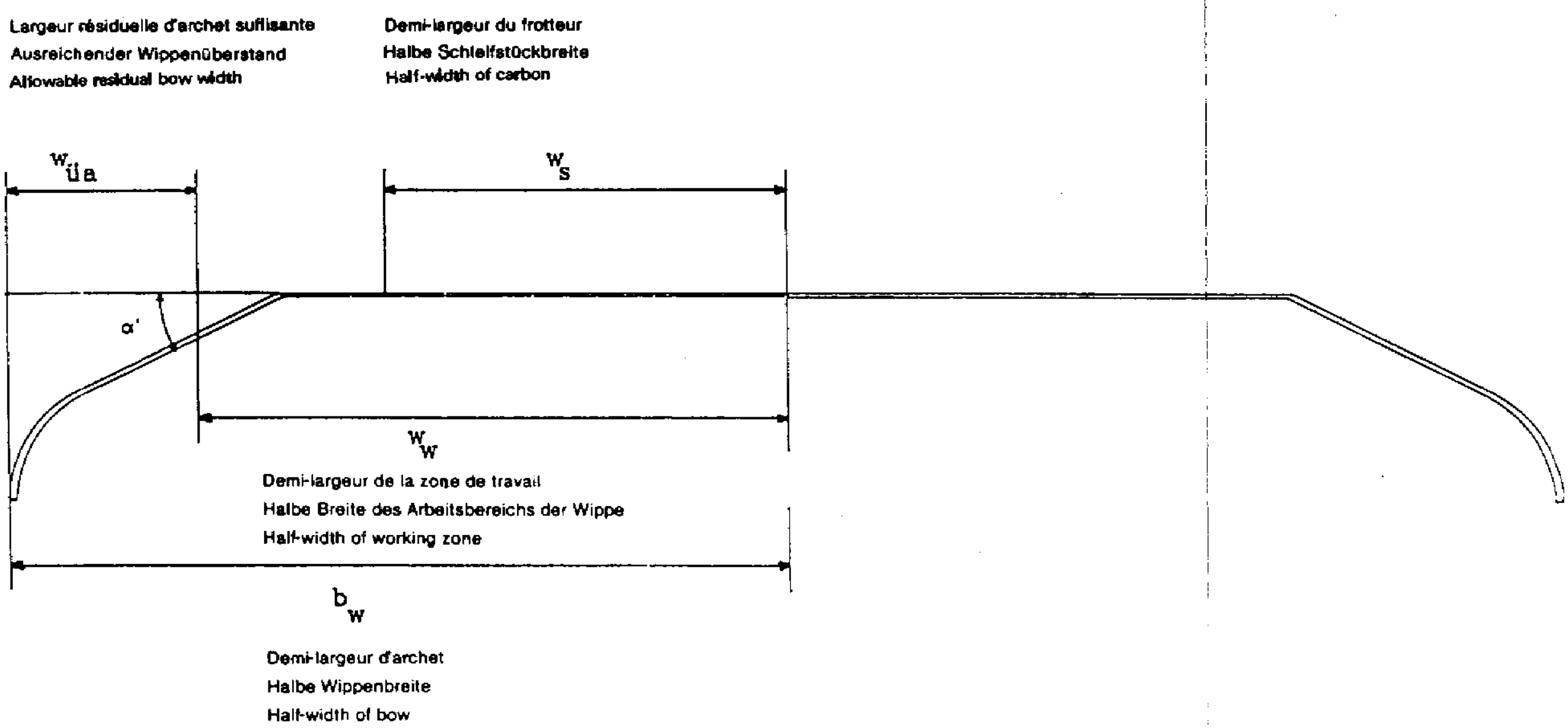


RAUM

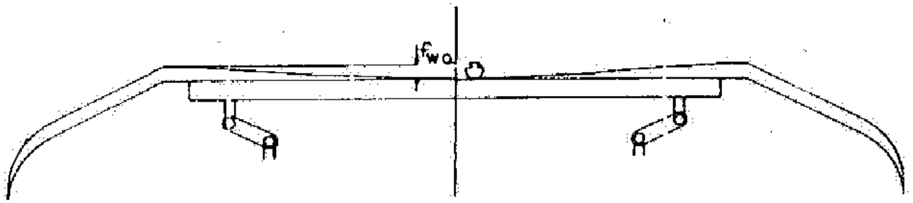
ESPACE POUR LA STRUCTURE LONGITUDINALE DE LA CATENAIRE 25 kV, 50 Hz Exemple de la SNCF
~~RAUEM~~ FUER DAS LAENGSKETTENWERK 25 kV, 50 Hz Am Beispiel der SNCF
SPACE FOR LONGITUDINAL STRUCTURE OF CATENARY 25 kV, 50 Hz SNCF Example



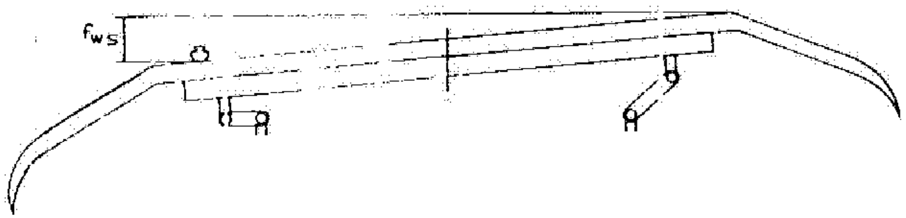
LARGEUR D'ARCHET, ZONE DE TRAVAIL, LARGEUR SUFFISANTE -
BREITE UND ARBEITSBEREICH DER WIPPE, AUSREICHENDER WIPPENUEBERSTAND -
WIDTH OF BOW, WORKING ZONE, ALLOWABLE RESIDUAL BOW WIDTH



EMPIÈTEMENT DE L'ARCHET AU-DELA DU PLAN DE CONTACT
HINAUSRAGEN DER WIPPE UEBER DIE SCHLEIFEBENE
ENCROACHMENT OF BOW BEYOND CONTACT PLANE



Axe du véhicule
Fahrzeugmittellinie
Centre line of vehicle



ELECTRICAL DISTANCES FOR THE VARIOUS VOLTAGES

	1.5 kV DC	3 kV DC	15 kV AC	25 kV AC	50 kV AC
b_1	0.010	0.010	0.020	0.030	0.050
b_2	0.010	0.010	0.030	0.040	0.060
b_3	0.010	0.010	0.020	0.050	0.070
b_4	0.020	0.020	0.030	0.030	0.080
b_5	0.050	0.050	0.100	0.100	0.180
b_6	0.060	0.060	0.070	0.070	0.160
normal distances dynamically without pollution 1)					
	0.100	0.100	0.150	0.170	0.350
normal distances dynamically with pollution 1)					
	0.110	0.110	0.170	0.220	0.420
minimum distances dynamically without pollution 1)					
	0.020	0.020	0.050	0.070	0.110
minimum distances dynamically with pollution 1)					
	0.030	0.030	0.070	0.120	0.180
normal distances static without pollution 2)					
	0.150	0.150	0.250	0.270	0.530
normal distances static with pollution 2)					
	0.160	0.160	0.270	0.320	0.600
minimum distances static without pollution 2)					
	0.090	0.090	0.180	0.200	0.370
minimum distances static with pollution 2)					
	0.100	0.100	0.200	0.250	0.440

Distances in m

The values indicated should be considered as minimum distances if it is not proved that local conditions enable them to be reduced.

1) Catenary set in motion (passage of pantograph, wind...) and vehicle in movement

2) Catenary immobile and vehicle stationary.

APPLICATION

With effect from 1 January 1987.

All Railways in the Union.

RECORD REFERENCES

Heading under which the question has been studied:

- Working Party 7/H - Leaflet 606-1 "Consequences of the application of the kinematic gauges defined by UIC leaflets in the 505 series on the design of the contact lines".
(Way and Works Committee: Paris, June 1986).

- Question 57/A/FIC - Item 5.3 - Other business.
(Way and Works Committee : Paris, June 1988).