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Railway applications — Current collection systems — Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line

National foreword

This British Standard is the UK implementation of EN 50317:2012. It supersedes BS EN 50317:2002+A2:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9/3, Railway Electrotechnical Applications - Fixed Equipment.

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Railway applications - Current collection systems - Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line

Applications ferroviaires -
Systèmes de captage de courant -
Prescriptions et validation des mesures de l'interaction dynamique entre le pantographe et la caténaire

Bahnanwendungen -
Stromabnahmesysteme -
Anforderungen und Validierung von Messungen des dynamischen Zusammenwirkens zwischen Stromabnehmer und Oberleitung

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Foreword

This document (EN 50317:2012) has been prepared by CLC/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".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-12-26
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2014-12-26

This document supersedes EN 50317:2002 + A1:2004 + A2:2007.

EN 50317:2012 includes the following significant technical changes with respect to EN 50317:2002 + A1:2004 + A2:2007:

- new definitions for “cord force”, “mean contact force” and “total mean uplift force” (Clause 3);
- updated abbreviation lists (Clause 4);
- requirements for examination of total mean uplift force and aerodynamic portions (new Clause 6);
- a clear relation between the different portions of contact force (7.1);
- limits for aerodynamic influences of the force measurement system (7.2);
- the aerodynamic correction for measured contact forces (7.4);
- corrections and elaborations for calibration of force measurement (7.5);
- adjustment of filter requirements (7.6);
- adjustment of accuracy requirements for measurement of displacements (Clause 8);
- updated requirements for measurement of arcing (Clause 9).

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For the relationship with EU Directive(s) 2008/57/EC, see informative Annex ZZ, which is an integral part of this document.

1 Scope

This European Standard specifies the functional requirements for output and accuracy of measurements of the dynamic interaction between pantograph and overhead contact line.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

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

3.1
collector head / pantograph head
pantograph equipment comprising the contact strips and their mountings

3.2
contact point
point of mechanical contact between a contact strip and a contact wire

3.3
working area of pantograph head
lateral and vertical range of possible contact points on the contact strips during normal operation

3.4
contact force
vertical force applied by the pantograph to the overhead contact line

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

3.5
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

3.6
static contact force
vertical force exerted upward by the collector head on the overhead contact line at standstill

3.7
standard deviation of contact force σ
square root of the sum of the square errors divided by the number of output values minus 1

3.8
aerodynamic force
additional vertical force applied by the pantograph as a result of air flow around the pantograph assembly. The aerodynamic force depends upon speed

3.9
statistical minimum of contact force
value of contact force represented by $F_m - 3\sigma$

3.10
statistical maximum of contact force
value of contact force represented by $F_m + 3\sigma$

3.11
cord force
measured force in a cord restraining a contact strip at a defined height

3.12
total mean uplift force
vertical force measured at the pantograph head, the latter not touching the contact line. It is equal to the sum of static contact force and the aerodynamic force caused by the air at the considered speed for a given height of contact points

3.13 transfer function magnitude
magnitude of the ratio between the applied and the measured forces of the pantograph and instrumentation determined by a dynamic excitation of the pantograph, at the pantograph head for a range of frequencies

3.14
tension length
length of overhead contact line between two terminating points
[SOURCE: EN 50119]

3.15
control section
representative part of the total measuring length, over which the measuring conditions are compliant with standard conditions

3.16
pantograph current
current that flows through the pantograph

3.17
arcs, arcing
flow of current through an air gap between a contact strip and a contact wire usually indicated by the emission of intense light

3.18
sensitivity curve
relationship between the power density of the arc in µW/cm² and the response of the detector in volts within the spectral range of interest

3.19
nominal current
current that flows through one pantograph for nominal power of train

3.20
percentage of arcing *NQ*
proportion of driving time with arcing

4 Abbreviations and symbols

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

a_{Sensori} acceleration measured in acceleration sensor i

d	measurement distance between arc detector and light source (contact strip)
d_{ref}	reference distance between arc detector and light source
$F_{applied}$	force applied to pantograph head
F_c	contact force
$F_{corraero}$	aerodynamic force correction (see 7.4)
F_m	mean contact force
$F_{measured}$	force measured
$F_{Sensori}$	measured force in sensor i
f_1	minimum frequency
f_i	actual frequency
f_n	maximum frequency
g	surface power density generated by the smallest arc that shall be detected at reference distance
J	accuracy of the transfer function
k_a	number of acceleration sensors
k_f	number of force sensors
m_{above}	mass between contact point and force sensors (see 7.3)
NQ	percentage of arcing
n	number of frequency steps
t_{arc}	duration of arcs recorded
t_{total}	measured duration with a pantograph current greater than a specified value
x	surface power density generated by the smallest arc that shall be detected at measurement distance
x_{ref}	surface power density generated by the smallest arc that shall be detected at reference distance
σ	standard deviation of contact force

5 General

The measurement of the interaction of the contact line and the pantograph is intended to prove the safety of operation and the quality of the current collection system. Results of measurements of different current collection systems shall be comparable, to approve components for free access within Europe.

NOTE Measured values are also required for validation of simulation programs and other measurement systems.

To check the performance capability of the current collection system at least the following data shall be measured:

– the contact wire uplift at the support as the pantograph passes;

and either

– the mean contact force and standard deviation

or

– the percentage of arcing.

In addition to the measured values, the operating conditions (train speed, location...) shall be recorded continuously and the environmental conditions (rain, ice, temperature, wind, tunnel...) and test configuration (parameters and arrangement of pantographs, type of overhead contact system...) during the measurement shall be recorded in the test report. This additional information shall ensure repeatability of the measurement and comparability of the results.

6 Measurement of total mean uplift force

Where a tethered test is used to measure the total mean uplift force the following requirements shall be fulfilled.

A tethered test determines cord force(s). The total mean uplift force is the sum of all mean values of the measured cord forces at the chosen height, speed and measurement conditions.

The aerodynamic force is the total mean uplift force minus the static contact force.

For this measurement the pantograph shall be restrained at a height as near as possible to the contact wire height for which the result shall be valid. The restraint shall be provided by vertical cords to each collector strip. The cords shall have adequate tensile stiffness, to constrain pitching of the head.

The accuracy of adjustment shall be checked on horizontal track without cant. The collector strips shall be adjusted so that the along track and cross track errors are less than 1,5° relative to plane of rails.

The contact wire shall not touch the pantograph during the test.

NOTE 1 A typical distance between collector head and contact wire is 10 cm to 15 cm.

The force in each cord shall be measured.

The dynamic behaviour of the cord forces depends on a number of influences (surrounding conditions, turbulence around the cords, track conditions, tunnels...).

To achieve confidence with the results the variance of the forces recorded and their repeatability over different sections shall be demonstrated.

The speed dependency shall be measured between 80 km/h and the maximum speed in steps. The step shall be chosen in accordance with the maximum train speed.

NOTE 2 A typical step is 20 km/h or 5 steps for the complete speed range.

In addition to the conditions recorded according to Clause 5, the train configuration and driving direction and also the restrained height and wear conditions of the collector strips shall be noted.

As a result of the tethered test the total mean uplift force as a function of speed for the measured configuration shall be presented.

7 Measurement of contact force

7.1 General requirements

The measurement of contact force shall be carried out on the pantograph using force sensors. The force sensors shall be located as near as practicable to the contact points.

The measurement system shall measure the vertical component of the contact forces, minimising interference from forces in other directions (e.g. contact friction).

All sensors shall be temperature compensated for the measuring conditions.

For pantographs with independent contact strips each contact strip shall be measured separately.

The measurement system shall be immune to electromagnetic interference.

Deviations from the original pantograph mass and geometry caused by installation of the measurement system shall be minimised.

The maximum error of the measurement system shall be less than 10 % of the measured value.

The contact force shall be calculated by the following formula which includes the signals from the force sensors and from the acceleration sensors (inertia correction, see 7.3) as well as the aerodynamic force correction (7.4)

$$F_c = \sum_{i=1}^{k_f} F_{Sensor,i} + \frac{m_{above}}{k_a} \cdot \sum_{i=1}^{k_a} a_{Sensor,i} + F_{corr,aero} \quad (1)$$

7.2 Aerodynamic influence of the measurement system

The measurement system shall not have any effects on the aerodynamic force that changes the total mean uplift force by more than 5 %.

NOTE The most important influence that a measurement system can create on the results is linked to the aerodynamic effect. This distortion can be checked by carrying out a measurement in accordance with Clause 6 with and without the measurement system under repeatable conditions (e.g. in a wind tunnel or with a line test).

7.3 Inertia correction

The inertia forces due to the effect of the mass of the components between the sensors and the contact point shall be corrected. This shall be achieved by measurement of the acceleration of these components.

7.4 Aerodynamic correction

A correction shall be applied to allow for the influence of aerodynamic forces on the components between sensors and the contact points.

This aerodynamic correction shall be derived from a measurement of total mean uplift force (e.g. via cords according to Clause 6) and simultaneously measuring the sensor forces.

The difference between the total mean uplift force and the mean of the sum of the sensor forces gives the aerodynamic correction for the measurement system of this pantograph.

The aerodynamic correction shall be established in the defined configuration.

NOTE The aerodynamic correction depends on contact wire height, train configuration, measurement equipment, environmental conditions, etc.

7.5 Calibration of the measurement system

The measurement system shall be laboratory tested to check the accuracy of the measured force. This test shall be carried out for the complete pantograph fitted with the complete force measurement devices and any accelerometers, the data transfer system (telemetry, optical systems) and amplifiers.

This test shall be carried out with the mean force equal to the static force. If the pantograph contact force increases with speed, the test shall also be carried out at the predicted mean contact force appropriate to the maximum train speed.

The transfer function magnitude shall be determined.

NOTE 1 If a sinusoidal force is applied an amplitude of ± 15 % of the predicted mean contact force gives representative results.

The tests shall be carried out for the two cases:

– The force being applied centrally to the pantograph head;

– The force being applied 250 mm from the centre line of the pantograph head, if possible. Otherwise the point of force application shall be as close as possible to this value. If another value is used, it shall be noted in the test report.

The test shall be carried with a pantograph extension equivalent to the restrained height used in Clause 6.

Measurements of the applied force and the measured force shall be taken at frequencies from 0,5 Hz up to 20 Hz in 0,5 Hz steps, with reduced intervals at resonant frequencies. The frequency steps near the resonant frequencies shall be specified.

NOTE 2 The transfer function is a continuous function with greater variations close to the resonant frequencies. Reduction of the frequency steps near the resonant frequencies is necessary.

The accuracy J of the transfer function magnitude shall be calculated by using the following formula:

$$J = \left(1 - \frac{1}{(f_n - f_1)} \sum_{i=1}^{n-1} \left((f_{i+1} - f_i) \left| 1 - \frac{F_{measured}}{F_{applied}} \right| \right) \right) \cdot 100\ \% \qquad (2)$$

The accuracy of the transfer function magnitude of the measurement systems shall be greater than 90 % up to a frequency limit of 20 Hz (in accordance with 7.1). To achieve this, a correction with filters can be made.

7.6 Measurement parameters

The sampling rate shall be greater than 200 Hz for time sampling or smaller than 0,40 m for distance sampling.

The contact force shall be low pass filtered with a cut-off frequency of 20 Hz. The filter shall be sixth order or higher. Either analogue or digital filters may be used.

The measuring range shall be at least:

- for AC-pantographs from 0 N to 500 N,
- for DC-pantographs from 0 N to 700 N.

7.7 Measurement results

Measurements taken within a control section shall be evaluated.

For calculating statistical values the control section should not be shorter than a tension length.

As a minimum the following statistical values of the filtered contact force shall be calculated for a control section:

- mean value (F_m);
- statistical maximum;
- statistical minimum;
- standard deviation (σ);
- histogram or probability curve.

8 Measurement of displacement

8.1 General

The measurement system shall not have any effects on the measured displacement which could change the result by more than 3 %.

8.2 Vertical displacement of the contact point

The vertical displacement of the contact point is measured relative to the base frame of the pantograph.

The accuracy of the measurement system shall be better than 10 mm.

8.3 Uplift at the support

The error of the measurement system shall be smaller than 5 mm. To ensure the measurements are representative the wind speed shall be recorded at the same location.

8.4 Measurement of other displacements in the overhead contact line

The accuracy of the measurement system shall be better than 10 % of the amplitude of the measured value or less than or equal to 10 mm, which ever gives a higher accuracy.

NOTE This accuracy is valid for measurements of movements of elements of overhead contact lines, e.g. to check electrical clearance under bridges.

9 Measurement of arcing

9.1 General requirements

For the detection of arcs the detector shall be sensitive to the wave lengths of light emitted by copper materials. For copper and copper alloyed contact wires a wave length range shall be used that includes the range 220 nm – 225 nm or 323 nm – 329 nm.

NOTE 1 These two wave length ranges have substantial copper emissivity.

The measurement system shall be insensitive to visible light with wave length greater than 330 nm.

The detector shall:

– be close enough to the pantograph to achieve a sufficiently high sensitivity,

– be close enough to the vehicle's longitudinal axis to achieve a sufficiently high sensitivity,

– be located behind the pantograph according to the direction of travel of the vehicle,

– aim at the trailing contact strip according to the direction of travel,

– be sensitive for a field of view over the whole working area of the pantograph head; the tolerance for this sensitivity shall be better than 10 %,

– have a response time to the beginning and end of an arc of less than 100 μs,

– have a detection threshold depending on the defined minimum power of arcs which shall be measured.

NOTE 2 The threshold values vary depending on the distance between measurement device and the place where the arcs occur.

A reference threshold (x_{ref}) with a related reference distance (d_{ref}) shall be defined, depending on the problem to be investigated.

NOTE 3 Common values of reference threshold (x_{ref}), to investigate current collection quality, with a reference distance (d_{ref}) of 5 m are:

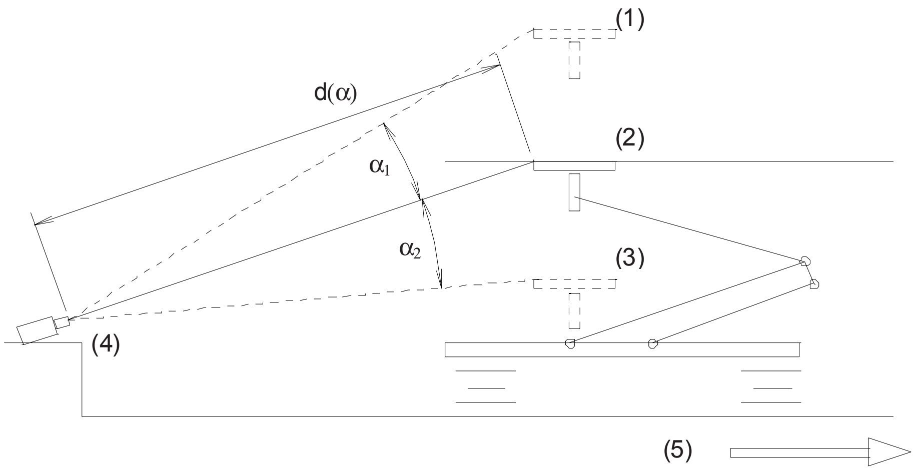
– 160 μW/cm² ± 10 % for use on 25 kV AC,

– 57,1 μW/cm² ± 10 % for use on 15 kV AC,

– 15,1 μW/cm² ± 10 % for use on 3 kV DC,

– 12,5 μW/cm² ± 10 % for use on 1,5 kV DC.

Figure 1 gives an example of the side view of the location of a detector.



Key

1 max working height of pantograph

2 nominal working height of pantograph

3 minimum working height of pantograph

4 arc detector location

5 driving direction

Figure 1 — Detector location

9.2 Calibration of the arc measurement system

The considered detector shall be calibrated for sensitivity to surface power density in the spectral range of interest according to 9.1.

The sensitivity curve shall be determined by measuring the analogue output of the detector in response to the calibrated light input on the sensor.

9.3 Adjustment of threshold for the measurement distance

If the distance between the sensor and the light source differs during measurement from the reference distance (d_{ref}), an adjustment of the threshold (x_{ref}) of the detector shall be carried out.

This shall be carried out as follows:

- determine the power density of the smallest arc that can be detected at reference distance in accordance with the $1/d^2$ law;
- use the reference values to determine the signal corresponding to this power density level;
- consequently, the value of power density threshold (x) to be detected is a function of the measurement distance (d) owing to the relation

$$x = x_{ref} \frac{d^2}{d_{ref}^2} \qquad (3)$$

NOTE An arc is considered to be a point source and consequently the power density is proportional to $1/d^2$ (see Figure 1).

9.4 Values to be measured

As a minimum the system shall measure:

- the duration of each arc,
- the train speed during the test,
- the pantograph current,
- the location of the arc along the overhead contact line (kilometric position).

9.5 Measurement results

The presentation of values shall be carried out for a control section. The control section should not be shorter than 10 km and should be travelled at a constant speed.

NOTE 1 A tolerance of ± 2,5 km/h is acceptable.

For the output, only arcs longer than a defined duration shall be analysed. Multiple consecutive arcs with gaps less than 100 µs shall be counted as continuous arcs.

NOTE 2 This duration depends of the problem which has to be investigated. A common value is 5 ms, when investigating current collection quality.

For output, only sections of line with a pantograph current greater 30 % of the nominal current per pantograph shall be analysed.

NOTE 3 To get representative results for the overhead contact line the total time with a pantograph current greater than 30 % of the nominal current should not be shorter than the time taken to travel over one tension length. This time should not be interrupted by sections with reduced currents and the speed should be constant.

The percentage of arcing (*NQ*) shall be calculated as:

$$NQ = \frac{\sum t_{arc}}{t_{total}} \cdot 100\ \% \qquad (4)$$

The percentage of arcing (*NQ*) is a characteristic for a given speed of the vehicle.

NOTE 4 Another possible criterion is the number of arcs per km with a pantograph current greater than 30 % of the nominal current.

As a minimum for the control section the following values shall be generated:

- train speed;
- the number of arcs;
- the sum of the duration of all arcs taken into consideration (t_{arc});
- the largest arc duration;
- the total time with a pantograph current greater than 30 % of the nominal current per pantograph (t_{total});
- the total run time for the control section;
- the percentage of arcing (*NQ*);

Annex ZZ
(informative)

Coverage of Essential Requirements of EU Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Union and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Annex III of the EU Directive 2008/57/EC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING: Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

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