



BSI Standards Publication

Railway applications — Aerodynamics

Part 4: Requirements and assessment procedures for aerodynamics on open track

National foreword

This British Standard is the UK implementation of EN 14067-4:2024+A1:2025. It supersedes BS EN 14067-4:2024, which is withdrawn.

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

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Exigences et procédures d'évaluation pour
l'aérodynamique à l'air libre

Bahnanwendungen - Aerodynamik - Teil 4:
Anforderungen und Bewertungsverfahren für
Aerodynamik auf offener Strecke

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European foreword

This document (EN 14067-4:2024+A1:2025) has been prepared by Technical Committee CEN/TC 256 “Railway Applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2025, and conflicting national standards shall be withdrawn at the latest by November 2025.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document includes Amendment 1 approved by CEN on 9 April 2025.

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This document has been prepared under a standardization request addressed to CEN by the European Commission.

EN 14067, *Railway applications — Aerodynamics* consists of the following parts:

- Part 4: Requirements and assessment procedures for aerodynamics on open track;
- Part 5: Requirements and assessment procedures for aerodynamics in tunnels;
- Part 6: Requirements and assessment procedures for cross wind assessment;
- Part 7 (TR): Fundamentals for test procedures for train-induced ballast projection.

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Introduction

Trains running on open track generate aerodynamic loads on objects and persons they pass. If trains are being passed by other trains, trains are also subject to aerodynamic loading themselves. The aerodynamic loading caused by a train passing an object or a person near the track, or when two trains pass each other, is an important interface parameter between the subsystems of rolling stock, infrastructure and operation. It is thus subject to regulation when specifying the trans-European railway system.

Trains running on open track must overcome a running resistance which has a strong effect on the required engine power, achievable speed, travel time and energy consumption. Thus, running resistance is often subject to contractual agreements and requires standardized test and assessment methods. The test set-up for ballast projection was also updated.

1 Scope

This document establishes requirements, test procedures, assessment methods and acceptance criteria for operating rolling stock in open track. For pressure variations and slipstream effects beside the track, requirements and assessment methods are provided. For running resistance, assessment methods are addressed in this document. Load cases on infrastructure components due to train-induced pressure variations and slipstream effects are addressed in this document. For ballasted track test set-ups for ballast projection assessment are proposed.

The requirements only apply to rolling stock of the heavy rail system with maximum train speeds above 160 km/h and not to other rail systems. The document is applicable to all rolling stock and infrastructure in open air with nominal track gauges of 1 435 mm to 1 668 mm inclusive.

2 Normative references

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

EN 1991-2:2003,¹ *Eurocode 1: Actions on structures — Part 2: Traffic loads on bridges*

EN 16727-2-2:2016, *Railway applications - Track - Noise barriers and related devices acting on airborne sound propagation - Non-acoustic performance - Part 2-2: Mechanical performance under dynamic loadings caused by passing trains - Calculation method*

EN 17343, *Railway applications - General terms and definitions*

ISO 8756, *Air quality — Handling of temperature, pressure and humidity data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 17343 and the following apply.

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

peak-to-peak pressure change

modulus of the difference between the maximum pressure and the minimum pressure for the relevant load case

3.2

passage of train head

passage of the front end of the leading vehicle which is responsible for the generation of the characteristic pressure rise and drop, over and beside the train and on the track bed

3.3

Computational Fluid Dynamics

CFD

numerical methods of approximating and solving the equations of fluid dynamics

¹ Document impacted by AC:2010.

3.4

streamline shaped vehicle

vehicle with a closed and smooth front which does not cause flow separations in the mean flow field greater than 5 cm from the side of the vehicle

3.5

bluff shaped vehicle

vehicle that is not streamline shaped

3.6

unit

rolling stock that may be composed of several vehicles

3.7

fixed train composition

train formation that can only be reconfigured within a workshop environment

3.8

pre-defined train compositions

train formation of one or several units coupled together, which is defined at design stage and can be reconfigured during operation

4 Symbols

For the purposes of this document, the symbols in Table 1 apply.

Table 1 — Symbols

Symbol	Unit	Significance	Explanation or remark
a	m/s ²	train accelerations measured during the coasting test	
a_D	m/s ²	train accelerations measured during the coasting test when the train is running downhill	
a_d	m/s ²	difference of train accelerations between two coasting tests at the same track location	
a_U	m/s ²	train accelerations measured during the coasting test when the train is running uphill	
C_F	–	coefficient of aerodynamic force	
C_{p1}	–	aerodynamic coefficient depending on the distance from track centre Y	
C_{p2}	–	aerodynamic coefficient depending on the height above top of rail h	

Symbol	Unit	Significance	Explanation or remark
C_{p3}	–	aerodynamic coefficient depending on the distance from track centre Y	
C_1	N	mechanical resistance	
$C_{1,A}$	N	approximation of mechanical resistance	see 7.4.2
$C_2 v_{tr}$	N	momentum resistance due to air flow for traction and auxiliary equipment and the air conditioning systems	
$C_3 v_{tr}^2$	N	aerodynamic resistance in the running resistance formula	
$\overline{C_3}$	N/Pa	$\overline{C_3}$ showing the density contribution	
c	m/s	speed of sound	
dt	s	temporal variation	
dv_{tr}	m/s	train speed variation	
dx	m	spatial variation	
F	N	load on an object, maximum value of the force during the passage	
F_d	N	force	see 7.4.2.2.3
g	m/s ²	acceleration due to gravity	
h	m	height above top of rail	
i	–	gradient of the track	within a typical range of $\pm 0,03$
k	–	factor accounting for the energy stored in rotating masses	$\geq 1,0$
k_{MU}	–	factor accounting for multiple units	see Formula (16)
k_1	–	shape coefficient of the train	
k_2	–	shape coefficient of the train	
k_3	–	shape coefficient of the train	
L_n	m	length of the train nose	distance from front end to where the full cross section of the leading vehicle is achieved

Symbol	Unit	Significance	Explanation or remark
L_s	m	length of test section	see 7.4.2.2
m	kg	train mass	
N_b	–	number of additional units compared with test configuration	see 7.2.2.1
P_d	N	function of train speed squared between two coasting tests at the same track location	see 7.4.2.4
p	Pa	pressure	
$p_{\max}$	Pa	maximum pressure	
$p_{\min}$	Pa	minimum pressure	
p_{1k}	Pa	characteristic value of distributed load	
p_{2k}	Pa	characteristic value of distributed load	
p_{3k}	Pa	characteristic value of distributed load	
$Re_{\max}$	–	maximum Reynolds number	based on reference length of 3 m at full scale
R_1	N	running resistance	train contribution, see 7.4.1
R_2	N	running resistance	infrastructure contribution, see 7.4.1
r_C	m	reference value of curve radius	see 7.4.2.4
r	m	curve radius	
S	m ²	characteristic area	
s	m	distance	see 7.4.2.2
t	s	time	
t_i	s	scaled time referring to the i -th passage	
$t_{m,i}$	s	time referring to the i -th passage	
U_i	m/s	maximum resultant horizontal air speed of the i -th passage after averaging and	

Symbol	Unit	Significance	Explanation or remark
		correction to the characteristic train speed	
$\bar{U}$	m/s	mean value over all measured maxima U_i	
$U_{\max}$	m/s	maximum value of U	
$U_{2\sigma}$	m/s	upper bound of a 2σ interval of maximum air speed	
$U_{95\%}$	m/s	maximum resultant horizontal air speed	characteristic air speed from measurement
$U_{95\%,\max}$	m/s	maximum permissible horizontal air speed	limit for characteristic air speed
$u_i(t_i)$	m/s	resultant horizontal air speed of the i -th passage	after transformation of the time base
$u_{m,i}(t_{m,i})$	m/s	measured resultant horizontal air speed of the i -th passage	
v_a	m/s	relative wind velocity	see Figure 1
v_d	m/s	difference of train speed between two coasting tests at the same track location	see 7.4.2.4
$v_{d,q}$	m ² /s ²	difference of train speed squared between two coasting tests at the same track location	see 7.4.2.4
v_{tr}	m/s	train speed	
v_{trD}	m/s	instantaneous train speed coasting downhill	see 7.4.2.2
$v_{tr,i}$	m/s	train speed during the i -th passage	
$v_{tr,\max}$	m/s	maximum train speed or design speed of a train	maximum train speed refers to train operation. if limited by infrastructure, maximum train speed may be lower than design speed.
$v_{tr,ref}$	m/s	reference speed	
$v_{tr,S1}$	m/s	measured speed at point S coasting uphill	see 7.4.2.2

Symbol	Unit	Significance	Explanation or remark
$v_{tr,S2}$	m/s	measured speed at point S coasting downhill	see 7.4.2.2
$v_{tr,S1a}$	m/s	measured speed at starting point S1 coasting direction 1	see 7.4.2.2.3
$v_{tr,S1b}$	m/s	measured speed at end point coasting direction 1	see 7.4.2.2.3
$v_{tr,S2a}$	m/s	measured speed at starting point S2 coasting direction 2	see 7.4.2.2.3
$v_{tr,S2b}$	m/s	measured speed at end point coasting direction 2	see 7.4.2.2.3
$v_{tr,test}$	m/s	nominal test speed	
v_{trU}	m/s	instantaneous train speed coasting uphill	see 7.4.2.2
v_w	m/s	wind speed	wind speed measured at stationary point, see Figure 1
$v_{w,x,i}$	m/s	wind speed component in x-direction during the i -th passage	
$v_{w,y,i}$	m/s	wind speed component in y-direction during the i -th passage	
W_y	–	quotient of cross wind speed and incident air speed in track direction	see 7.1.2.1
Y	m	lateral distance from track centre	
Y_{min}	m	minimum lateral distance from track centre	
Y_{max}	m	maximum lateral distance from track centre	
y^+	–	dimensionless wall distance	
β	°	yaw angle	angle between the vehicle axis and the relative wind acting on the train. In a wind tunnel with stationary train model, it is the angle between the train axis and the wind tunnel axis, see Figure 1.

Symbol	Unit	Significance	Explanation or remark
ΔC_p	–	pressure change coefficient	
$\Delta C_{p,2\sigma}$	–	pressure change coefficient	upper bound of a 2σ interval of the peak-to-peak pressure change coefficient. The peak-to-peak pressure change coefficient is defined in Formula (2).
Δp	Pa	peak-to-peak pressure change	
$\overline{\Delta p}$	Pa	mean value for peak-to-peak pressure change	determined over all measurements Δp_i or by CFD
Δp_i	Pa	corrected maximum peak-to-peak pressure value of the i -th passage	Formula (5)
$\Delta p_{m,i}$	Pa	maximum peak-to-peak pressure value measured during the i -th passage	Formula (5)
Δp_{sim}	Pa	the head pressure variation from unsteady CFD calculations	
$\overline{\Delta p_{\text{sim}}}$	Pa	the average of head pressure variation from CFD calculations	the average refers either to steady CFD calculations or the average of results from unsteady simulations
$\overline{\Delta p_{\text{sim},k}}$	Pa	head pressure variation from steady CFD calculations for the k -th height	Formula (6)
$\Delta p_{\text{test},k}$	Pa	average peak-to-peak pressure value for the 6 heights k , taken from measurements	Formula (8)
$\Delta p_{2\sigma}$	Pa	upper bound of a 2σ interval of the peak-to-peak pressure change	
$\Delta p_{95\%}$	Pa	maximum peak-to-peak pressure change	characteristic pressure change
$\Delta p_{95\%,\text{max}}$	Pa	permissible maximum peak-to-peak pressure change	permissible characteristic pressure change

Symbol	Unit	Significance	Explanation or remark
Δt	s	characteristic time interval	passage of train head, time between pressure peaks
ε	-	relative root mean square of the difference between a calculated pressure variation and test results	
η	Pa s	dynamic viscosity of air	
ρ	kg/m ³	air density	
ρ_i	kg/m ³	air density determined during the i -th passage	
ρ_0	kg/m ³	standard air density	$\rho_0 = 1,225 \text{ kg/m}^3$
σ	-	standard deviation	can be pressure or speed
σ_{sim}	Pa	standard deviation of simulated pressure	

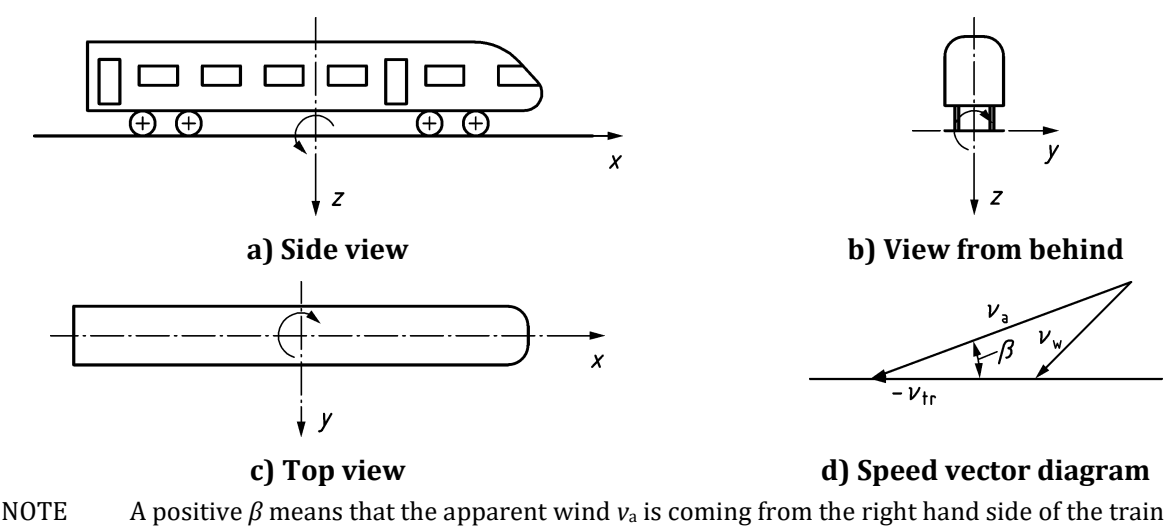


Figure 1 — Coordinate system

5 Requirements on locomotives and passenger rolling stock

5.1 Limitation of pressure variations beside the track

5.1.1 General

A passing train generates a varying pressure field beside the track which has an effect on objects such as crossing trains, noise barriers, platform installations, etc. To define a clear interface between the subsystems of rolling stock and infrastructure, the train-induced aerodynamic pressure loads beside the track need to be known and limited.

In order to describe and to limit the train-induced aerodynamic pressure loads beside the track reference cases for rolling stock assessment are defined for track gauges from 1 435 mm to 1 668 mm inclusive.

5.1.2 Requirements

5.1.2.1 Reference case

For track gauges from 1 435 mm to 1 668 mm the pressure field generated by a passing train at a distance according to Table 2 from the centre of the track is referred to as the reference case. The reference case is defined for a straight track with standard track formation profile and in the absence of embankments, cuttings and other significant trackside structures. The pressure variations occurring are limited by the permissible pressure change $\Delta p_{95\%,\max}$, which refers to the maximum pressure change that occurs during the passage of the leading vehicle.

5.1.2.2 Fixed or pre-defined train compositions

A fixed or pre-defined train composition, running at the reference speed in the reference case scenario shall not cause the maximum peak-to-peak pressure changes to exceed a value $\Delta p_{95\%,\max}$ as set out in Table 2 over the range of heights 1,50 m to 3,00 m above the top of rail during the passage of the train head. For non-identical end cars the requirement applies for each possible running direction.

Table 2 — Maximum permissible peak-to-peak pressure change $\Delta p_{95\%,\max}$ depending on maximum design speed

Track gauge	Maximum design speed	Measurement distance from track centre	Permissible pressure change $\Delta p_{95\%,\max}$ at reference speed	Reference speed
mm	km/h	m	Pa	km/h
any	$v_{tr,\max} \leq 160$	2,50	no requirement	
1 435	$160 < v_{tr,\max} < 250$	2,50	$\Delta p_{95\%,\max} = 800$	$v_{tr,\max}$
1 435	$250 \leq v_{tr,\max}$	2,50	$\Delta p_{95\%,\max} = 800$	250
1 524	$160 < v_{tr,\max} < 250$	2,50	$\Delta p_{95\%,\max} = 1\,600$	$v_{tr,\max}$
1 668	$160 < v_{tr,\max} < 250$	2,60	$\Delta p_{95\%,\max} = 800$	$v_{tr,\max}$
1 668	$250 \leq v_{tr,\max}$	2,60	$\Delta p_{95\%,\max} = 800$	250

5.1.2.3 Vehicle capable of running in leading position

A vehicle capable of running in leading position shall not cause the maximum peak-to-peak pressure changes to exceed a value $\Delta p_{95\%,\max}$ as set out in Table 2, when running as the leading vehicle at the reference speed in the reference case scenario. The range of heights to be considered are 1,50 m to 3,00 m above the top of rail during the passage of the front end of this vehicle. For vehicles capable of bidirectional operation as a leading vehicle, the requirement applies when the vehicle is placed in leading position for each running direction.

5.1.2.4 Other rolling stock

For other rolling stock which are not covered in 5.1.2.2 or 5.1.2.3 there are no requirements.

5.1.3 Full conformity assessment

A full conformity assessment of interoperable rolling stock shall be undertaken according to Table 3.

Table 3 — Methods applicable for the full conformity assessment of rolling stock

Maximum design speed	Methods
$v_{tr,\max} \leq 160 \text{ km/h}$	No assessment needed
$160 \text{ km/h} < v_{tr,\max}$	Assessment by: <ul style="list-style-type: none"> — full-scale tests according to 7.1.2.1; or — reduced-scale moving model tests according to 7.1.2.2; or — computational fluid dynamics (CFD) simulations according to 7.1.2.4

5.1.4 Simplified conformity assessment

A simplified conformity assessment may be carried out for rolling stock that are subject to minor design differences in comparison to rolling stock for which a full conformity assessment already exists.

With respect to pressure variations beside the track, the only relevant design differences are differences in external geometry and differences in design speed.

This simplified conformity assessment shall take one of the following forms in accordance with Table 4:

- a statement and rationale that the design differences have no impact on the pressure variations beside the track;
- a comparative evaluation of the design differences relevant to the rolling stock for which a full conformity assessment already exists.

Table 4 — Methods and requirements applicable for simplified conformity assessment of rolling stock

Design differences	Methods and requirements
<p>Differences in external geometry limited to</p> <ul style="list-style-type: none"> — locations either downstream from the maximum cross-section of the train nose or downstream from the minimum pressure peak relative to the train nose, — the inner region of the underbody of the train (under the train and between rails), — minor differences in external geometry, — wipers and handles, — antennae with a volume smaller than 5 000 cm³, — long isolated protruding objects or gaps not being vertical or close to the front-side radius or edge smaller than 50 mm in the crosswise dimensions, — small isolated protruding objects and gaps smaller than 50 mm in each dimension. 	<p>Documentation of differences, statement of no impact and reference to an existing compliant full conformity assessment.</p>
<p>Other differences in external geometry (e.g. in buffers, front couplers, snow ploughs, front or side windows) keeping the basic head shape features.</p>	<p>Documentation of differences and reference to an existing compliant full conformity assessment AND assessment of the relative effect of differences by</p> <ul style="list-style-type: none"> — reduced-scale moving model tests according to 7.1.2.2 or — CFD-simulations according to 7.1.2.4, AND evidence and documentation that <p>1) the difference causes changes in $\overline{\Delta p}$ less than $\pm 10 \%$,</p> $\frac{\overline{\Delta p}(B) - \overline{\Delta p}(A)}{\overline{\Delta p}(A)} < 0,1$ <p>AND</p> <p>2) the difference does not exceed 50 % of the margin available on the compliance with 5.1.2.</p> $(\overline{\Delta p}(B) - \overline{\Delta p}(A)) < 0,5 \times (\Delta p_{95\%,\max} - \Delta p_{95\%}(A))$ <p>NOTE B refers to the new train geometry. A refers to the existing compliant train.</p>
<p>Increase of design speed</p> <ul style="list-style-type: none"> — less than 10 % for a train with original design speed < 250 km/h, — for a train with original design speed ≥ 250 km/h. 	<p>Documentation of differences and reference to an existing compliant full conformity assessment AND evidence and documentation based on a ΔC_p analysis that the new design under investigation still fulfils the requirements listed in 5.1.2.</p>

5.2 Limitation of slipstream effects beside the track

5.2.1 General

A train generates a varying flow field beside the track which has an effect on persons and objects at the track side and at platforms. Therefore, measurements at two heights shall be undertaken representing the position of track workers and passengers. In order to define a clear interface between the subsystems of the rolling stock and the infrastructure, the train-induced slipstream effects need to be known and limited.

In order to describe and to limit the train-induced slipstream effects, reference cases for rolling stock assessment are defined for track gauges from 1 435 mm to 1 668 mm inclusive.

NOTE Ensuring track workers' and passengers' safety at the platform involves additional measures on the operational and infrastructure side.

5.2.2 Requirements

5.2.2.1 Reference cases

For track gauges from 1 435 mm to 1 668 mm inclusive and in the absence of embankments, cuttings and any significant trackside structures, the undisturbed flow field generated by a passing train at a distance according to Table 5 from the centre of a straight track with standard track formation profile is referred to as the reference case. The air flows occurring are limited by the permissible horizontal air speed $U_{95\%,\max}$ which refers to the whole passage of the train and its wake, see Table 5. One of the following three reference cases shall be considered:

- for fixed or pre-defined train compositions, see 5.2.2.2;
- for vehicle capable of running in leading position, see 5.2.2.3; for other rolling stock, see 5.2.2.4.

5.2.2.2 Fixed or pre-defined train compositions

A maximum length, fixed or pre-defined train composition with maximum number of units, running at reference speed in the reference case scenario shall not cause the maximum resultant horizontal air speeds $U_{95\%}$ to exceed the values $U_{95\%,\max}$ as set out in Table 5 at heights of 0,20 m and 1,40 m above the top of rail during the passage of the whole train and its wake. For non-symmetrical train compositions, the requirement applies for each possible running direction. If applicable, the choice of train configurations assessed shall be documented addressing length and number of units as well as the symmetry (comparing front half to back half of train). The choice of variations in positioning coaches within the train shall be justified.

The requirement is applicable to train compositions up to 415 m. Longer train compositions require further investigation and assessment.

Table 5 — Maximum permissible horizontal air speed $U_{95\%,\max}$ depending on maximum design speed

Track gauge mm	Maximum design speed $v_{tr,\max}$ km/h	Height above the top of rail m	Distance from the track centre m	Permissible horizontal air speed $U_{95\%,\max}$ at reference speed m/s	Reference speed $v_{tr,ref}$
any	$v_{tr,\max} \leq 160$	no requirement			
1 435	$160 < v_{tr,\max} < 250$	0,20	3,00	$U_{95\%,\max} = 20,0$	the maximum design speed
		1,40	3,00	$U_{95\%,\max} = 15,5$	200 km/h or maximum design speed, if lower than 200 km/h
	$250 \leq v_{tr,\max}$	0,20	3,00	$U_{95\%,\max} = 22,0$	300 km/h or maximum design speed, if lower than 300 km/h
		1,40	3,00	$U_{95\%,\max} = 15,5$	200 km/h
1 524	$160 < v_{tr,\max} < 250$	0,20	3,00	$U_{95\%,\max} = 22,5$	the maximum design speed
		1,40	3,00	$U_{95\%,\max} = 18,0$	200 km/h or maximum design speed, if lower than 200 km/h
1 668	$160 < v_{tr,\max} < 250$	0,20	3,10	$U_{95\%,\max} = 20,0$	the maximum design speed
		1,40	3,10	$U_{95\%,\max} = 15,5$	200 km/h or maximum design speed, if lower than 200 km/h
	$250 \leq v_{tr,\max}$	0,20	3,10	$U_{95\%,\max} = 22,0$	300 km/h or maximum design speed, if lower than 300 km/h
		1,40	3,10	$U_{95\%,\max} = 15,5$	200 km/h

NOTE 1 The measurement height of 0,20 m in Table 5 represents a situation related to track workers, see TSI HS RST 2008, 4.2.6.2.1. The height of 1,40 m represents a situation related to passengers on a platform, see TSI HS RST 2008, 4.2.6.2.2.

NOTE 2 In EN 14067-4:2005+A1:2009 and TSI HS RST 2008 there was a requirement to make measurement of velocity at 1,20 m above a low height platform as well as at trackside. The measurement at trackside at 1,40 m height was demonstrated in a series of tests to be equivalent to the measurement on the platform.