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Railway applications - Aerodynamics - Part 5: Requirements and test procedures for aerodynamics in tunnels

Bahnanwendungen - Aerodynamik - Teil 5: Anforderungen und Prüfverfahren für Aerodynamik im Tunnel

Applications ferroviaires - Aerodynamique - Partie 5 : Exigences et procédures d'essai pour l'aérodynamique en tunnel

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This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 256.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (prEN 14067-5:2018) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 14067-5:2006+A1:2010.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2008/57/EC.

For relationship with EU Directive 2008/57/EC, see informative Annex ZA, which is an integral part of this document.

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

— *Part 1: Symbols and units*;

— *Part 3: Aerodynamics in tunnels*;

— *Part 4: Requirements and test procedures for aerodynamics on open track*;

— *Part 5: Requirements and test procedures for aerodynamics in tunnels*;

— *Part 6: Requirements and test procedures for cross wind assessment.*

The results of the EU-funded research project “AeroTRAIN” (Grant Agreement No. 233985) have been used.

The contents of the previous edition of EN 14067-5 have been integrated in this document; they have been re-structured and extended to support the Technical Specifications for the Interoperability of the Trans-European rail system. Requirements on conformity assessment for rolling stock were added.

1 Scope

This document establishes requirements, test procedures, assessment methods and acceptance criteria for aerodynamics in tunnels and rolling stock in tunnels. Topics of aerodynamic pressures and loadings, aerodynamic resistance and micro-pressure waves are addressed.

Requirements for rolling stock with operating speeds equal to or above 200 km/h are provided for pressures generated in tunnel operation. Requirements for infrastructure with design speeds above 160 km/h or high blockage ratio or tunnels longer than 12 km are provided for pressures generated in tunnel operation. These requirements are not applicable to light rail and urban rail.

This document is applicable to all railway vehicles and infrastructure with track gauges from 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 12663-1, *Railway applications — Structural requirements of railway vehicle bodies — Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons)*

EN 12663-2:2010, *Railway applications — Structural requirements of railway vehicle bodies — Part 2: Freight wagons*

EN 14067-4:2013, *Railway applications — Aerodynamics — Part 4: Requirements and test procedures for aerodynamics on open track*

EN 15273 (all parts), *Railway applications — Gauges*

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

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:

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

3.1
compression wave
approximate step change in pressure above ambient that travels at the speed of sound

3.2
expansion wave
approximate step change in pressure below ambient that travels at the speed of sound

3.3
Computational Fluid Dynamics
(CFD)
numerical methods of approximating and solving the formulae of fluid dynamics

3.4
exceptional loads
maximum loads occurring occasionally during normal operations due to both static and transient loads

3.5
fatigue loads
very large number of dynamic and aerodynamic loads of varying magnitude that the structures of rail vehicle bodies or infrastructure components are subjected to during their operational life

3.6
static loads
loads that are constant or nearly constant with time

Note 1 to entry: These loads include the dynamic pressure due to the airflow acceleration around the front of the train and pressure changes caused by strong side winds.

3.7
transient loads
loads that vary in time

Note 1 to entry: Transient loads can be divided into three kinds:

a) loads caused by trains running in the open air, due to the pressure field around the train;

b) loads caused by trains travelling alone or crossing with other trains in tunnels;

c) loads that arise due to the turbulent nature of the flow around trains.

Note 2 to entry: Loads a) and b) are relevant for all train structures, but loads c) may be only relevant for some high speed train components and are not considered in this standard.

3.8
tunnel
excavation or a construction around the track provided to allow the railway to pass through, for example, higher land, buildings or water

Note 1 to entry: A tunnel in the context of this standard has a length greater than 100 m.

3.9
tunnel length
length of a tunnel is defined as the length of the fully enclosed section, measured centrally at rail level

3.10
tunnel cross-sectional area (for blockage ratio)
free cross-sectional area of a tunnel not including ballast rail, sleepers, longitudinal piping, platform

3.11
vehicle cross-sectional area (for blockage ratio)
cross-sectional area of a vehicle in lengthwise direction

4 Symbols and abbreviations

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

Table 1 — Symbols

Symbol	Significance	Explanation or remark	Unit
A_S, A_T	area of integration	see Figure 11	sPa
A_{tu}	tunnel free cross-sectional area		m^2
B, B1, B2	train/tunnel blockage ratio	$B = \frac{S_{tr}}{S_{tu}}$	
b	width of vehicle		m
$C_{f,tr}$	train friction factor or coefficient		
$C_{f,tu}$	tunnel friction factor or coefficient		
C_n	factor depending on the shape of the train nose and the shape of the tunnel portal	Formula (C.2)	
$C_{oa,cros}$	load collective for trains encountering on the open track		
$C_{tu,solo}$	collective for solo passages in the tunnel		
CFL	Courant-Friedrich-Levy number		
c	speed of sound		m/s
D_h	hydraulic diameter		m
F_{max}	maximum measured force	see Figure D.4	N
g	acceleration due to gravity		m/s^2
h	height		m
h_l	frequenciey corresponding to a class of amplitudes in a rainflow matrix		
h_0	distance from top of rail to the underside of the carbody		m
h_c	height of tunnel centre above ground		m
Δh	difference between maximum and minimum altitudes in the tunnel		m
H, H_1, H_2	relative humidity of air		%
k	Wöhler curve exponent		
k	vehicle structural rigidity factor		
k_j	factor		
k_s	train roughness parameter		m
L_n	nose length of train		m
$L_{tu,crit}$	critical tunnel length		m
L_{veh}	length of the vehicle		m
$L_{section,i}$	length of the route section		km

L_{tr}	length of train		m
L_{tu}	length of tunnel		m
$L_{tu,min}$	minimum length in a tunnel	measured from entry portal	m
$L_{virttun}$	virtual length of the tunnel		m
L_{year}	Mileage per year		km/year
N_{oa}	sections of open track		1/year
N_c	reference cycle		
$N_{trainsperhour}$	Number of trains passing a stationary point in one direction per hour		1/h
$N_{tu,cros}$	Number of tunnels, in which trains encounter		
$N_{tu,solo}$	Number of tunnels, in which solo passages occur		
$n_{oa,cros,i}$	frequency for trains crossing on the open track		
$n_{tu,cros,j}$	frequency for trains crossing in a double track tunnel		
$n_{tu,solo,i}$	frequency of single train passages without train encounter in a double track tunnel		
Pe_{tr}	perimeter of train		m
Pe_{tu}	perimeter of tunnel		m
p	pressure		Pa
p_{eq}	damage-equivalent amplitude		Pa
p_l	classified amplitude		Pa
p_L	pressure load		Pa
p_{atm}	atmospheric pressure		Pa
p_d	pressure difference between external and internal pressure		Pa
p_e	external pressure	outside of a vehicle	Pa
p_i	internal pressure	in a vehicle	Pa
p_o	reference static pressure		Pa
p_{offset}	offset pressure		Pa
$p(t)_{sim}$	pressure signal in tunnel from simulation software		Pa
$p(t)_{test}$	pressure signal in tunnel from track test		Pa
r	radius	distance between tunnel exit portal centre (on the ground) and the point of interest (reception point), see Annex C	m

r_b	corner radius of the micro-pressure wave reference vehicle		m
R	tunnel radius		m
S_{eq}	equivalent leakage area		m^2
S_{tr}	Train cross-sectional area	see 3.10	m^2
S_{tu}	Tunnel cross-sectional area	see 3.9	m^2
t, t_A, t_B, t_S, t_T	time		s
t_e	difference in entry time		s
t_{life}	Train service life		year
T	absolute temperature		K
T_f	tunnel factor		
U	local dominant speed (train speed or pressure wave speed)	see 7.6.2	m/s
U_0	flow velocity in tunnel relative to train before train entry		m/s
v_{tr}	train speed		m/s
$v_{tr,1}$	train speed	see 7.7.4.3	m/s
$v_{tr,2}$	speed of the encountering train	see 7.7.4.3	m/s
$v_{max, line}$	maximum line speed or design speed of a line		km/h
$v_{tr,max}$	maximum train speed or design speed of a train	Maximum train speed referes to train operation If limited by infrastructure, maximum train speed may be lower than design speed	km/h
$v_{tr,ref}$	train reference speed		km/h
$v_{tr,test}$	train test speed		m/s
V_{int}	internal volume of the vehicle		m^3
X_d, X_h, X_{fr}, X_t	dummy variables		
x_p	distance between the entrance portal and the measuring position		m
x_1, x_2, x_3	longitudinal positions on the train	defined in 7.7.3.4	m
Y_{tr}	track distance	centre to centre	m
ΔL_1	additional length		m
$\Delta p, \Delta p(t)$	differential pressure at time t		Pa
Δp_{alt}	natural pressure variation due to altitude		Pa
$\Delta p_{d,max}$	maximum difference between internal and external pressures	see Figure D.4	

Δp_{fr}	pressure change due to friction effects caused by the entry of the main part of the train into the tunnel	see Figure 6	
$\Delta p_{fr,o}$	pressure change due to friction effects caused by the entry of the main part of the train into the tunnel	see 7.2.4	Pa
Δp_{HP}	pressure signature caused by the passing of the train nose at the measurement position in the tunnel	see Figure 6	Pa
Δp_{max}	maximum peak-to-peak pressure change on outside of train		Pa
Δp_{N}	pressure change caused by the entry of the nose of the train into a tunnel	see Figure 6	Pa
$\Delta p_{N,o}$	pressure change caused by the entry of the nose of the train into a tunnel measured on a train on the exterior of the train	see 7.2.4	Pa
Δp_{T}	pressure change caused by the entry of the tail of the train into a tunnel	see Figure 6	Pa
$\Delta p_{T,o}$	pressure change caused by the entry of the tail of the train into a tunnel measured on the exterior of a train	see 7.2.4	Pa
Δp_{1}	pressure after train tail entrance	see A.3.2	Pa
$\overline{\Delta p}_{N}$	average nose entry pressure change		Pa
$\overline{\Delta p}_{fr}$	average frictional pressure rise		Pa
$\overline{\Delta p}_{T}$	average tail entry pressure change		Pa
Δt	characteristic time interval for the pressure rise		
Δt_{e}	time increment		s
$\Delta t_{e,min}$	lower bound of entry time interval		s
$\Delta t_{e,max}$	upper bound of entry time interval		s
Δx_{1}	additional distance		m
$\varepsilon_{\Delta p}$	deviation between test and simulation		
ζ_{E}	loss coefficient for tunnel portal		
ζ_{h}	loss coefficient of the train nose in the tunnel		
ζ_{h0}	loss coefficient of the train nose in the open air		
ζ_{h1}	coefficient for additional loss of the train nose in the tunnel		
ζ_{t}	loss coefficient of the train tail in the tunnel		

ζ_{t0}	loss coefficient of the train tail in the open air		
ζ_{t1}	coefficient for additional loss of the train tail in the tunnel		
ζ_1	loss coefficient for the train		
ζ_N	train nose pressure loss coefficient		
ζ_P	tunnel portal pressure loss coefficient		
ζ_T	train tail pressure loss coefficient		
θ	temperature		°C
ρ_{amb}	ambient atmospheric air density		kg/m^3
ρ, ρ_1, ρ_2	air density		kg/m^3
τ_{dyn}	tau-model, representing train operation; values of pressure tightness coefficient for moving rail vehicles		s
τ_{stat}	values of pressure tightness coefficient for static rail vehicles		
Ω	solid angle representing the configuration around the tunnel exit portal		
$\overline{}$, (overbar)	average of the value		

5 Requirements on locomotives and passenger rolling stock

5.1 Limitation of pressure variations inside tunnels

5.1.1 General

When a train enters and exits a tunnel, pressure variations are generated which propagate along the tunnel at sonic speed and are reflected back at portals into the tunnel. These pressure variations may cause aural discomfort or, in the worst case, aural damage, to train passengers and train staff and will produce transient loads on the structure of trains and the infrastructure components.

To define a clear interface between the subsystems of rolling stock and infrastructure in the heavy rail system, the train-induced aerodynamic pressure variations inside tunnels need to be known and limited. In order to describe and to limit the train-induced aerodynamic pressure variations inside tunnels, two reference cases for rolling stock assessment are defined.

5.1.2 Requirements

5.1.2.1 Reference case

For track gauges from 1 435 mm to 1 668 mm inclusive, the pressure variations generated by a train entering a simple, non-inclined tube-like tunnel, (i.e. without any shafts, etc.), are defined by pressure signatures for two given combinations of train speed and tunnel cross-section. The latter are referred to as the reference cases.

The pressure signature consists of three characteristic pressure variations: Δp_N caused by the entry of the nose of the train into the tunnel, Δp_{fr} due to friction effects caused by the entry of the main part of the train into the tunnel, and Δp_T caused by the entry of the tail of the train into the tunnel (see Figure 6).

NOTE Compliance with this requirement does not necessarily ensure free access to all lines.

The assessment shall be made for standard meteorological conditions: atmospheric pressure p_{atm} = 101 325 Pa, air density ρ_{amb} = 1,225 kg/m^3, temperature θ = 15 °C with no initial air flow in the tunnel.

Table 2 — Maximum tunnel characteristic pressure changes Δp_{fr}, Δp_N and Δp_T for the reference case

Maximum design speed/class km/h	**Reference case**		**Criteria for the reference case**		
	Reference speed, $v_{tr,ref}$ km/h	A_{tu} m^2	Δp_N Pa	$\Delta p_N + \Delta p_{fr}$ Pa	$\Delta p_N + \Delta p_{fr} + \Delta p_T$ **Pa**
$v_{tr,max}$ < 200	**No requirement**				
200 ≤ $v_{tr,max}$ < 250 (Class 2)	200	53,6	≤ 1 750	≤ 3 000	**≤ 3 700**
250 ≤ $v_{tr,max}$ (Class 1)	**250**	**63,0**	**≤ 1 600**	**≤ 3 000**	**≤ 4 100**

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 tunnel scenario without crossing other trains shall not cause the characteristic pressure variations at a fixed point in the tunnel to exceed the values set out in Table 2.

NOTE Fixed and pre-defined train compositions are described in TSI LOC&PAS 2014, Section 2.2.1.

For train compositions that are non-symmetrical with respect to running direction, the requirement applies for both running directions.

For fixed or pre-defined train compositions consisting of more than one train unit, the full assessment shall be made for the maximum length of the train of coupled units, see 7.3.

Full scale tests provide input data for the assessment and may be carried out using shorter train configurations, see 7.2.2.3.

5.1.2.3 Single rolling stock units fitted with a driver's cab

A single unit fitted with a driver's cab running as the leading vehicle at the reference speed in the reference case tunnel scenario without crossing other trains shall not cause the characteristic pressure variations Δp_N and Δp_T to exceed the values set out in Table 2. The pressure variation Δp_{fr} shall be set to 1 250 Pa for trains with $v_{tr,max}$ < 250 km/h or, respectively to 1 400 Pa for trains with $v_{tr,max}$ ≥ 250 km/h.

For single rolling stock units capable of bidirectional operation as a leading vehicle the requirement applies for both running directions.

5.1.2.4 Other passenger rolling stock

Other passenger rolling stock running at the reference speed in the reference case tunnel scenario shall not cause the characteristic pressure variations Δp_{fr} to exceed the values set out in Table 2. The