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VERBAND DEUTSCHER VERKEHRSUNTERNEHMEN

Guideline

Detailed definition and clarification of open points in the aerodynamic requirements of TSI HS RST 2008 and TSI CR LOC&PAS 2011 in 4.2.6.2.1 passengers on platform, 4.2.6.2.2 workers at the track side and 4.2.6.2.3 head pressure pulse

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1 Introduction / Motivation

Conformity assessments are needed for the homologation of railway vehicles regarding pressure loads during train-head passage and velocity loads while a train passes in its longest (coupled) configuration. The documented evidences of conformity are to be provided by means of full-scale measurements; the conformity assessment is documented in TSI HS RST 2008 [1] and TSI CR LOC&PAS 2011 [2] and lower-ranking in EN 14067-4:2005+A1:2009 [3]. The conformity assessments have to be conducted for construction velocities higher than 160 km/h. This applies for both pre-defined train configurations and single vehicles. The threshold values noted in the technical guidelines mentioned before serve for the safety of passengers on platforms and workers at the track during train passage. Additionally, they serve for a limitation of aerodynamic loads on infrastructure components, as there are sound protection walls or the loads on other railway vehicles during passage.

There are fields in the previously mentioned technical guidelines, which have not been clearly defined up to date. Following points are notably among them:

- The conformity assessment for the homologation of minor modifications on vehicles, where a homologation already exists. These changes refer to modifications of the outer geometry, which subsequently could lead to the modification of the pressure and flow circumstances at the railway vehicle, but which are so small, that that they could be disregarded or rather do not have any influence on the threshold values outlined in the technical guidelines because of their position, for example. Modifications which thus have a minor but insignificant effect on the homologation can be dealt with by means of a simplified verification process.
- In TSI CR LOC&PAS 2011 chapter 4.2.6.2 open points exist for the conformity assessment of velocity and pressure loads of single vehicles for general operation (refers to vehicles were train formation is not fixed or defined at design stage) which may be addressed by national regulation.
- Also, the conformity assessments of pressure and velocity loads of single vehicles for general operation are not addressed in TSI HS RST 2008 in practice.
  This means in particular:
  - There are no concrete rules for single vehicles for general operation (particularly locomotives) with a driver's cab in which train formation and at which length conformity has to be proven.
  - There are no concrete rules for single vehicles without a driver's cab in which train formation and at which length conformity has to be proven.
  - Regarding the pressure loads caused by single vehicles with and without a driver's cab beside the track (head pressure pulse), there are open points in the definition of the arrangement of waggons for the conformity assessment.

Thus, the main goal of this guideline shall be to answer the existent open points and additionally clarify the verification methods and procedures in advance to the application of a new TSI LOC&PAS (see final draft V2.5 [4]) and FprEN 14067-4:2012 (agreed draft see [5]). Additionally, already agreed amendments in standardization drafts shall be picked up with this document and introduced at least for application in Germany, in order to facilitate the homologation process until the new standards come into force and also to facilitate the homologation of rolling stock based on TSI HS RST 2008 and TSI CR LOC&PAS 2011. Therefore, this guideline is applicable for all performed conformity assessments according to TSI HS RST 2008 and TSI CR LOC&PAS 2011.

2 List of open points and regulation gaps in TSI HS RST 2008 and TSI CR LOC&PAS 2011

Table 1. Listing of open points and regulation gaps in EN and TSI

Open Point TSI/EN / Regulation gap	Problem description	Dealing in this guideline	Reference in FprEN 14067-4:2012 / draft TSI LOC&PAS 2013
TSI LOC&PAS 2011 chapter 4.2.6.2.1 open point	Conformity assessment of velocity loads on platforms for configurations in general train operation mode (block train not defined, single vehicles)	See chapter 6.4 and 6.5	See chapter 4.2 (EN) / chapter 4.2.6.2.1 (TSI)
TSI LOC&PAS 2011 chapter 4.2.6.2.2 open point	Conformity assessment of velocity loads at a track for configurations in general train operation mode (train formation not defined, single vehicles)	See chapter 6.4 and 6.5	See chapter 4.2 (EN) / chapter 4.2.6.2.1 (TSI)
TSI HS RST 2008 chapter 4.2.6.2.1 regulation gap	The Conformity assessment of velocity loads on platforms for previously undefined train compositions and single vehicles is not addressed	See chapter 6.4 and 6.5	See chapter 4.2 (EN) / chapter 4.2.6.2.1 (TSI)
TSI HS RST 2008 chapter 4.2.6.2.2 regulation gap	The conformity assessment of velocity loads at a track for previously undefined train compositions and single vehicles is not addressed	See chapter 6.4 and 6.5	See chapter 4.2 (EN) / chapter 4.2.6.2.1 (TSI)
TSI HS RST 2008 chapter 4.2.6.2.3 regulation gap	The conformity assessment for single vehicles is not addressed	See chapter 7.4 and 7.5	See chapter 4.1.2 (EN) / chapter 4.2.6.2.2 (TSI)
Dealing with minor changes in the train geometry – not addressed in TSI and EN	Minor, for the conformity assessment of train aerodynamics irrelevant geometrical modifications (for example the attachment of an antenna in the underfloor region)	See chapter 6.6 and 7.6	See chapter 4.1.4 and 4.2.4 (EN)

3 Effectiveness of this document

This guideline shall apply to the homologation of railway vehicles in Germany according to TSI HS RST 2008 or TSI CR LOC&PAS 2011.

The guideline specifies open or unaddressed points in the TSI's and thereby simplifies (efficient train length in full-scale measurements, drop out of repeated measurements respectively) and accelerates the homologation process (coordination, negotiation) respectively.

The guideline sets up specifying rules, which are not or are only insufficiently addressed in the previously named technical regulations; it does not change the existing requirements or threshold values in the named TSI's, though. The regulating contents of the guideline rely on the status of FprEN 14067:2012 [5], voted in February 2013 in the Commons Resolution Meeting of the CEN; by that, the continuity with future standardization is ensured. After the new FprEN14067-4:2012 will be coming into force, the standardization can be used instead of this guideline.

4 Field of application

This document is valid for standard-gauge vehicles according to EBO with operation speeds higher than 160 km/h and is not applicable on freight vehicles.

5 Definitions and symbols

The following symbols are used for the purpose of this document.

$\Delta p_{2\sigma}$	Peak-to-peak pressure change according to TSI
Δc_p	Dimensionless pressure coefficient according to EN 4067-4
$u_{2\sigma}$	Train-induced air velocity according to TSI
v_{tr}	Train velocity
$v_{(tr,max)}$	Maximum operation velocity of the train
CFD	Computational Fluid Dynamics

Additional terms and symbols are specified in the standardization series EN 14067.

6 Limitation of slipstream effects beside the track

6.1 Terms in the TSI's

In the following, the formulation in the treated TSI's is reproduced in italic style. Requirements for the train formation to be examined are highlighted in bold style.

6.1.1 TSI HS RST 2008

4.2.6.2.1. Aerodynamic loads on track workers at the lineside

A full length train *running in the open air at 300 km/h or at its maximum operating speed* $v_{tr,max}$ *if lower than 300 km/h shall not cause an exceedance of the air speed u2σ at the trackside as set out in Table 9, at a height of 0,2 m above the top of rail and at a distance of 3,0 m from the track centre, during the passage of the whole train (including the wake).*

For trains with a maximum speed higher than 300 km/h, the measures to be taken by Infrastructure Manager are mentioned in clause 4.4.3 of the High Speed Infrastructure TSI.

Table 9

Trackside maximum permissible air speed

Maximum train speed $v_{tr,max}$ (km/h)	Trackside maximum permissible air speed, (limit values for $u_{2\sigma}$ (m/s))
From 190 to 249	20
From 250 to 300	22

Test conditions

(Further text see TSI, there is no relation to the guideline)

Conformity assessment

Conformity shall be assessed on the basis of full-scale tests and with the ***maximum length of the defined formations****.*

Detailed specifications

(Further text see TSI, there is no relation to the guideline)

4.2.1.6.2. Aerodynamic loads on passengers on a platform

A full length train*, running in the open air at a reference speed v_{tr} = 200 km/h, (or at its maximum operating speed $v_{tr,max}$, if this is lower than 200 km/h), shall not cause the air speed to exceed value $u_{2\sigma}$ = 15,5 m/s at a height of 1,2 m above the platform and at a distance of 3,0 m from the track centre, during the whole train passage (including the wake).*

Test conditions

(Further text see TSI, there is no relation to the guideline)

Conformity assessment

Conformity shall be assessed on the basis of full-scale tests and with the ***maximum length of the defined formations****.*

Detailed specifications

(Further text see TSI, there is no relation to the guideline)

6.1.2 TSI CR LOC&PAS 2011

4.2.6.2.1 Slipstream effects on passengers on platform

Rolling stock running in the open air at a maximum operating speed v_{tr} > 160 km/h, shall not cause the air speed to exceed value $u_{2\sigma}$ = 15,5 m/s at a height of 1,2 m above the platform and at a distance of 3,0 m from the track centre, during the passage of rolling stock.

The train formation to be used for test is specified below for different types of rolling stock:

- *Unit assessed in* ***fixed or predefined formation***

The full length of the fixed or the maximum length of the pre-defined formation (i.e. the maximum number of units permitted to be coupled together)

- *Unit assessed for use in **general operation** (**train formation not defined at design stage**): **open point***

Further information regarding testing, following the above mentioned point in the TSI in chapter 6.2.2.2.10 is irrelevant for the guideline.

4.2.6.2.2 Slipstream effects on workers at the track side

Rolling stock running in the open air at a maximum operating speed v_{tr} > 160 km/h, shall not cause the air speed to exceed a value $u_{2\sigma}$ = 20 m/s at the trackside as measured at a height of 0,2 m above top of rail and at a distance of 3,0 m from the track centre during the passage of rolling stock.

The train formation to be used for test is specified below for the different types of rolling stock:

- *Unit assessed in **fixed or predefined formation***

  The full length of the fixed or the maximum length of the pre-defined formation (i.e. the maximum number of units permitted to be coupled together)

- *Unit assessed for use in **general operation** (**train formation not defined at design stage**): **open point***

Further information regarding testing, following the above mentioned point in the TSI in chapter 6.2.2.2.11 is irrelevant for the guideline.

6.2 Introduction

A train induces a changing flow field beside the track during passage, which could affect the stability of persons at the track side and on platforms unfavourably. In order to define a clear interface between the subsystem railway vehicle and the infrastructure (e.g. definition of hazard areas by infrastructure officers), the train-induced aerodynamic effects of railway vehicles are limited by requirements in the TSI's.

The conformity assessment for slipstream effects beside the track and on a platform is performed in full-scale measurements with the assessed vehicle according to TSI HS RST 2008 and TSI CR LOC&PAS 2011, clause 4.2.6.2.1 and 4.2.6.2.2 respectively.

Depending on the type of vehicle, this guideline provides in chapter 6.3, 6.4 and 6.5 in clarification to the TSI, which train formations shall be taken into account during testing. All requirements and the description of the procedure of the full-scale measurements as well as the threshold values to be considered are still valid and described in TSI HS RST 2008 and TSI CR LOC&PAS 2011 in the chapters 4.2.6.2.1 and 4.2.6.2.2, respectively.

If modifications are performed to requirement compliant railway vehicles, the question will arise whether the conformity assessment remains valid or which steps are needed for a conformity assessment. In analogy to the agreed procedure of the draft FprEN 14067-4:2012 a simplified conformity assessment shall be applied in given cases; this is illustrated in chapter 6.6.

6.3 Requirements for fixed or pre-defined train compositions

The conformity assessment is performed with a formation of maximum length, compliant to TSI HS RST 2008 and TSI CR LOC&PAS 2011 (clauses 4.2.6.2.1 and 4.2.6.2.2). For fixed or predefined train

compositions consisting of more than one train unit, it is sufficient to assess a train composition consisting at least of two units and of a minimum length of 120 m.

6.4 Requirements for single units in general operation fitted with a driver's cab

Conformity shall be assessed for the units at the front and rear of a rake of passenger carriages of at least 100 min length. Assessments shall be carried out with either one unit, or with two identical units, one at the front and one at the rear of the train. The carriages should be comprised of those likely to be used in operational conditions.

Annotation of the AK Aerodynamik: in the testing of driving trailers, the position of a locomotive in the formation can be chosen freely.

6.5 Requirements for other railway vehicles

For railway vehicles, where 6.3 and 6.4 do not apply to, the following is valid: those railway vehicles coming under this chapter will be compliant (even without an experimental assessment), if similar to existing or proven compliant single rolling stock with respect to:

- design speed (lower or equal to existing); and
- bogie external arrangement (position, cavity and bogie envelope); and
- train envelope (i.e. body width, height) changes above the bogies of less than 10 cm.

The similarity and compliance for this approach shall be documented!

If this criterion does not apply, the vehicle should be tested in two configurations with the rolling stock likely to be used in operation; positioned directly behind an existing or proven compliant locomotive with a rake of carriages of at least 100 m in length behind it, and at the rear of a rake of carriages at least 100 m in length behind a compliant locomotive. If the coach has a dedicated purpose, e.g. restaurant car, which will dictate its position to be always mid-train, it should be tested only in the middle of a rake of carriages at least 100 m long.

6.6 Simplified conformity assessment

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

With respect to resultant horizontal air speeds 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 following forms in accordance with table 2.:

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

Table 2. Methods and requirements applicable for simplified conformity assessment of rolling stock

Design difference	Method /requirement
Differences in external geometry limited to • the inner region of the underpart of the train (under the train and between rails), • roof equipment, namely pantographs, antennae, electrical wiring and pipes, • other roof equipment changes smaller than 20 cm in each physical dimension, • fittings, seals, bonded joints, handles and handle bars, wipers, rear view installations, surface roughness, doors, windows, glazing, signal lights, pipes, cabling and plugs, • other parts with changes in lateral dimensions smaller than 5 cm.	Documentation of differences, statement of no impact and reference to an existing compliant conformity assessment
Other differences in external geometry keeping the basic head shape features.	Documentation of differences and reference to an existing compliant conformity assessment and assessment of relative effect of differences by • Tests with moved models, see clause 5.4.3 in EN 14067-4:2005+A1:2009 respectively newer versions of EN 14067-4, AND • evidence and documentation that a) the difference does not cause changes in bigger than ±10 % in $U_{2\sigma}$ and b) that the new design is still compliant to the requirements regarding the flow velocity $U_{2\sigma}$ following the TSI's (based on the original value from the documented evidence and the relative aberrations)
Decrease in design speed	Documentation of differences and reference to an existing compliant conformity assessment
Increase of design speed less than the smaller of 20 km/h or 10 % for a train with original design speed < 300 km/h	Documentation of differences and reference to an existing compliant conformity assessment. Evidence and documentation based on linear extrapolation of slipstream velocity $U_{2\sigma}$ at new design speed that the new design under investigation still fulfils the requirements of the TSI [1],[2].
Increase of design speed for a train with original design speed ≥ 300 km/h.	Documentation of differences and reference to an existing compliant conformity assessment.

7 Limitation of pressure variations beside the track

7.1 Terms in the TSI's

In the following, the formulation in the treated TSI's is reproduced in italic style. Requirements for the train formation to be examined are highlighted in bold style.

7.1.1 TSI HS RST 2008

4.2.6.2.3. Pressure loads in open air

***A full length train**, running at a given speed (reference case) in the open air shall not cause the maximum peak-to-peak pressure of changes to exceed a value $\Delta p_{2\sigma}$ as set out in Table 10 over the range of heights 1,5 m to 3,3 m above the top of rail, and at a distance of 2,5 m from the track centre, during the whole train passage (including the passing of the head, couplings and tail). The maximum peak-to-peak pressure changes are tabulated below:*

Table 10

Maximum permissible pressure changes in open air

Train	Reference train speed	Maximum permissible pressure change $\Delta p_{2\sigma}$
Class 1	250 km/h	795 Pa
Class 2	At maximum speed	720 Pa

Conformity assessment

*Conformity shall be assessed on the basis of full-scale tests and with a **maximum length of the defined formations**.*

Detailed specifications

(Further text see TSI, there is no relation to the guideline)

7.1.2 TSI CR LOC&PAS 2011

4.2.6.2.3. Head pressure pulse

The crossing of two trains generates an aerodynamic load on each of the two trains. The requirement below on head pressure pulse in open air allows defining a limit aerodynamic load during the crossing of two trains that has to be considered for the design of rolling stock, assuming a track centre distance of 4,0 m.

Rolling stock running with a speed higher than 160 km/h in the open air shall not cause the maximum peak-to-peak pressure of changes to exceed a value $\Delta p_{2\sigma}$ of 720 Pa as measured over the range of height between 1,5 m and 3,3 m above the top of rail, and at a distance of 2,5 m from the track centre, during the passage of the head.

The formation to be verified by a test is specified below for different types of rolling stock:

- *Unit assessed in **fixed or predefined formation***
  A single unit of the fixed formation or any configuration of the pre-defined formation.
- *Unit assessed for use in **general operation** (**train formation not defined at design stage**)*
- *Unit fitted with **a drivers cab** shall be assessed alone.*
- ***Other units**: Requirement not applicable.*

6.2.2.2.12 Head pressure pulse (clause 4.2.6.2.3)

Conformity shall be assessed on the basis of full-scale tests under conditions specified in EN 14067-4:2005/A1:2009 clause 5.5.2. Alternatively, and limited for speeds below 190 km/h, conformity may be assessed by means of either validated computational fluid dynamics (CFD) simulations as described in clause 5.3 of EN 14067-4:2005/A1:2009 or as an additional alternative conformity is permitted to be assessed by moving model tests as specified in EN 14067-4:2005/A1:2009 clause 5.4.3.

7.2 Introduction

During its passage, a train induces pressure variations, which act as a load on objects at the track, as there are noise barriers, platform canopies or crossing trains. The highest pressure values are expected for the passage of the train head. In order to define a clear interface for the subsystem railway vehicle, requirements are formulated for railway vehicles in order to limit aerodynamic pressure loads. The procedure of pressure evaluation as a conformity assessment for railway vehicles is documented in TSI HS RST 2008 and in TSI CR LOC&PAS 2011 in chapter 4.2.6.2.1 and 4.2.6.2.2, respectively. Regarding TSI CR LOC&PAS 2011, no further clarification is needed for the train formations to be examined.

7.3 Requirements for fixed or pre-defined train compositions

TSI CR LOC&PAS 2011 applies.

TSI HS RST 2008 applies.

7.4 Requirements for single units in general operation fitted with a driver's cab

TSI CR LOC&PAS 2011 applies.

For conformity assessments following TSI HS RST 2008, only single vehicles with a driver's cab shall be tested in leading position. For single rolling stock units capable of bidirectional operation as a leading vehicle, the requirement applies for each possible running direction.

Amendment of the AK: the evaluation of measurement data is to be performed for a time interval of one second before and after the passage of the train head according to [5]. Although there are no requirements for the choice of the subsequent vehicles, it is recommendable to choose the length of the train configuration in that manner, that the rear pressure wave does not coincide with the measurement interval.

7.5 Other railway vehicles

No conformity assessment has to be performed for other vehicles.

7.6 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 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 3:

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

Table 3: Methods and requirements applicable for simplified conformity assessment of RST

Design modifications	Methods and requirements
Differences in external geometry limited to: • locations either downstream of the distance of the maximum cross-section from the train nose or downstream of the distance of the minimum pressure peak relative to the train nose; • the inner region of the underpart of the train (under the train and between rails); • minor differences in external geometry; • wipers and handles; • antennae with a volume smaller than 5 litres; • 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.	Documentation of differences, statement of no impact and reference to an existing compliant conformity assessment.
Other differences in external geometry (e.g. in buffers, front couplers, snow ploughs, front or side windows) keeping the basic head shape features.	Documentation of differences and reference to an existing compliant conformity assessment AND Assessment of the relative effect of differences by • reduced-scale moving model tests according to chapter 5.4.3 of EN 14067-4:2005+A1:2009 respectively newer versions of EN 14067-4 • CFD-simulations according chapter 5.3 to of EN 14067-4:2005+A1:2009 respectively newer versions of EN 14067-4 AND evidence and documentation that a) The difference causes changes in $\overline{\Delta p}$ less than ±10 %. $\frac{\overline{\Delta p}(B) - \overline{\Delta p}(A)}{\overline{\Delta p}(A)} < 0{,}1$ NOTE B refers to the new train geometry. A refers to the existing compliant train. and b) The difference does not exceed 50 % of the following safety margin $\left(\overline{\Delta p}(B) - \overline{\Delta p}(A)\right) < 0{,}5 * \left(\Delta p_{2\sigma,max} - \Delta p_{2\sigma}(A)\right)$
Increase of design speed • less than 10 % for a train with original design speed < 250 km/h; • for a train with original design speed ≥250 km/h.	Documentation of differences and reference to an existing compliant conformity assessment AND evidence and documentation based on a Δc_p analysis that the new design under investigation still fulfils the requirements regarding the threshold values in the TSI.

8 Abstract

This guideline fills in open points in TSI CR LOC&PAS 2011 and put more detail to procedures in TSI HS RST 2008 regards homologation tests for pressure variations induced by the head pressure pulse and slipstream effects generated by the train passing by. Additionally, in case of minor modifications of the outer geometry of compliant railway vehicles, simplified procedures of conformity assessment are outlined and the prerequisites for them are illustrated.

The application of the guideline affects conformity assessments for railway vehicles regarding aerodynamics in TSI HS RST 2008 and TSI CR LOC&PAS 2011. Simplifications and clarifications, which will also be provided in the amended TSI LOC & PAS, can be used via the guideline for conformity assessments based on the TSI HS RST 2008 and TSI CR LOC&PAS 2011 and thus significantly simplify the process of conformity assessment.

9 Release note

This guideline was prepared by Arbeitskreis Aerodynamik on behalf of Lenkungskreis Fahrzeuge and released for submission to the LK Fahrzeuge on 14th May 2013. The LK Fahrzeuge approved the guideline for publication and submission as a Technical Opinion via EBA to the EU on its meeting on 12th June 2013. In parallel, the guideline can be submitted via EBA/EBC to NB Rail.

10 Bibliography

With regard to content, the drafts of TSI LOC&PAS 2013 and FprEN 14067-4:2012 available during preparation served as guidelines. Additionally, the TSI's valid up to date, TSI HS RST 2008 and TSI CR LOC&PAS 2011, and the standard EN 14067-4:2005+A1:2009 were applied.

[1] TSI HS RST 2008, "COMMISSION DECISION of 21 February 2008 concerning a technical specification for interoperability relating to the 'rolling stock' sub-system of the trans-European high-speed rail system", 2008/232/CE, March 2008

[2] TSI CR LOC&PAS 2011, "COMMISSION DECISION of 26 April 2011 concerning a technical specification for interoperability relating to the rolling stock subsystem – 'Locomotives and passenger rolling stock' of the trans-European conventional rail system", 2011/291/EU, May 2011

[3] EN 14067-4:2005+A1:2009, Railway applications – Aerodynamics – Part 4: Requirements and test procedures for aerodynamics on open track

[4] Final Draft of the TSI LOC&PAS 2013, "EUROPEAN UNION RAIL SYSTEM, SUBSYSTEM ROLLING STOCK, TSI LOCOMOTIVES AND PASSENGER RST", Version 2.5, 30/04/2013

[5] FprEN 14067-4:2012, Railway applications — Aerodynamics — Part 4: Requirements and test procedures for aerodynamics on open track, CEN/TC 256 Date: 2012-12