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Železniške naprave - Vozna sredstva - Specifikacija in preverjanje porabe energije

Specification and verification of energy consumption for railway rolling stock

Spezifikation und Überprüfung des Energieverbrauchs von Schienenfahrzeugen

Spécification et vérification de la consommation d'énergie pour le matériel roulant ferroviaire

Ta slovenski standard je istoveten z: EN 50591:2019

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Bahnanwendungen - Fahrzeuge - Spezifikation und Überprüfung des Energieverbrauchs

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European foreword

This document (EN 50591:2019) has been prepared by CLC/SC 9XB “Electrical, electronic and electromechanical material on board rolling stock, including associated software” with contribution of UNIFE-UIC TECREC 100_001.

The following dates are fixed:

— latest date by which the existence of this document has to be announced at national level	(doa)	2019-11-02
— latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2020-02-02
— latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2022-08-02

This document supersedes CLC/TS 50591:2013.

The main changes in this edition compared to CLC/TS 50591:2013 are the adoption of existing CLC/TS 50591 enquiry comments, the harmonization with results from the European Lighthouse Project Roll2Rail and the inclusion of an HVAC energy quantification method. Since separate methods for traction and HVAC energy quantification are described, the document structure had to be revised.

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

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

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

1 Scope

The purpose of this document is to support rolling stock procurement, especially life cycle cost (LCC) assessment.

This document is applicable to the specification and verification of energy consumption of railway rolling stock. It establishes a criterion for the energy consumption of rolling stock to calculate the total net energy consumed, either at current collector or from the fuel tank, over a predefined service profile, to ensure that the results are directly comparable or representative of the real operation of the train. For this purpose, this document considers the energy consumed and regenerated by the rolling stock. The determination methods covered are the simulation and the measurement.

This document provides the framework that gives guidance on the generation of comparable energy performance values for trains and locomotives on a common basis and thereby supports benchmarking and improvement of the energy efficiency of rail vehicles.

This document does not cover the comparison of energy consumption with other modes of transportation, or even for comparison between diesel and electric traction, covering only the energy consumption of the railway rolling stock itself.

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 13129:2016, *Railway applications – Air conditioning for main line rolling stock – Comfort parameters and type tests*

EN 15663:2017+A1:2018, *Railway applications – Vehicle reference masses*

EN 50163:2004, *Railway applications – Supply voltages of traction systems*

EN 50388:2012, *Railway Applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability*

EN 50463-1:2017, *Railway applications – Energy measurement on board trains – Part 1: General*

EN 50463-2:2017, *Railway applications – Energy measurement on board trains – Part 2: Energy measuring*

UIC leaflet 552, *Electrical power supply for trains – Standard technical characteristics of the train line* (10th edition, June 2005)

3 Terms, definitions and abbreviations

3.1 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

NOTE When possible, the following definitions have been taken from the relevant chapters of the International Electrotechnical Vocabulary (IEV), IEC 60050. In such cases, the appropriate IEV reference is given. Certain new definitions or modifications of IEV definitions have been added in this standard in order to facilitate

understanding. Expression of the performance of electrical and electronic measuring equipment has been taken from EN 60359:2002.

3.1.1
comfort systems
all equipment consuming energy for passenger and crew comfort belonging neither to the traction equipment nor to traction auxiliaries, mainly for the provision of a comfortable environment (for example lighting, heating, air conditioning, toilets, information and entertainment systems, laptop supplies)

Note 1 to entry: Comfort systems are split in two groups for use in this standard: Heating, Ventilation and Air Conditioning (HVAC) and Other comfort functions.

3.1.2
consist
single vehicle or a group of vehicles which are not separated during normal operation

Note 1 to entry: A consist can contain no, one or several consist networks.

[SOURCE: IEC 60050-811:2017, 811-37-20]

3.1.3
contact line
conductor system for supplying electric energy to vehicles through current-collecting equipment

[SOURCE: IEC 60050-811:2017, 811-33-01, modified – the Note 1 to entry has been omitted.]

3.1.4
electric traction system
railway electric distribution network (infrastructure) used to provide energy for rolling stock

[SOURCE: IEC 60050-811:2017, 811-36-21, modified – "(infrastructure)" has been added and the Note 1 to entry has been omitted.]

3.1.5
energy storage system
ESS
physical system which is comprised of energy storage technologies such as batteries, double-layer capacitors, flywheel, etc. and other equipment to connect the storage technologies to traction equipment, including control, cooling and monitoring systems

3.1.6
heating, ventilation and air conditioning
HVAC
system to provide heating, ventilation and air conditioning for comfort

3.1.7
infrastructure
fixed installations of the railway system (for example tracks, power supply, signalling, communication)

3.1.8
net energy
difference between the energy taken (consumed) from the contact line, fuel tank by the traction unit, and the energy fed back (regenerated) into the contact line by the traction unit

3.1.9
primary power source
subsystem in a hybrid system the primary purpose of which is to supply energy to other subsystems in the hybrid system by either consuming the fuel stored on-board or taking in energy from external source

3.1.10
regenerative braking <of a vehicle>
braking in which the energy produced by the motors is fed into the line or used by on-board devices

[SOURCE: IEC 60050-811:2017, 811-06-25, modified – “electro-dynamic” and “contact” have been removed, “into energy storage” has been replaced with “or used by”, and the Note 1 to entry has been omitted.]

3.1.11
rolling stock
all vehicles with or without motors

Note 1 to entry: Examples of vehicles include a locomotive, a coach and a wagon.

[SOURCE: IEC 60050-811:2017, 811-02-01]

3.1.12
service profile
outline of the expected range and variation in the mission with respect to parameters such as time, loading, speed, distance, stops, tunnels, etc., in the commercial exploitation of the train

3.1.13
single-train run
run of one train over a part of the infrastructure, without inclusion of effects of other trains

3.1.14
state of energy
SoE
remaining energy to be discharged, normally expressed as a percentage of full energy

[SOURCE: EN 62864-1:2016, 3.1.14, modified – the end of the definition “as expressed in relevant standards” has been removed and the Note 1 to entry has been omitted.]

3.1.15
traction auxiliaries
equipment needed to operate the traction equipment and the train in normal operation mode, but not producing tractive or dynamic braking efforts themselves (for example cooling fans, oil and water pumps, compressor, air supply for brakes, HVAC for the leading driver’s cabin, train control and management system and signalling equipment)

3.1.16
traction equipment
equipment on-board of the train directly needed to produce tractive or dynamic braking effort (for example transformers, converters, motors, gearboxes, internal combustion engines, fuel cells, energy storage systems)

3.1.17
traction unit
locomotive, motor coach or train-unit

[SOURCE: IEC 60050-811:2017, 811-02-04]

3.1.18
train
combination of rolling stock coupled together

[SOURCE: IEC 60050-811:2017, 811-01-08, modified – the Note 1 to entry has been omitted.]

3.1.19
user-defined service profile
service profile which is defined by the user for the comparison of the energy consumption of trains

Note 1 to entry: It is also intended for the comparison of simulations and real tests of the energy consumption of trains on an existing infrastructure.

3.2 Abbreviations

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

AC	Alternating Current
DC	Direct Current
ESS	Energy Storage System
HVAC	Heating, Ventilation and Air Conditioning System
LCC	Life Cycle Cost
SoE	State of Energy
UIC	Union Internationale des Chemins de Fer

4 General

Energy is an integral quantity. This means that the cumulated energy is the decisive factor. Realistic train operation always takes place under the constraints of infrastructure and operational requirements.

The following train modes are used in this standard:

— **In-service with commercial operation mode:**

This mode covers the normal operation of a train, including several passenger load cases or a locomotive hauling a consist of freight wagons. The train is moving or is stationary and the HVAC system is running in its normal operation mode.

— **In-service without commercial operation mode:**

In this mode a passenger train is stationary, the HVAC system is in operation as for commercial operation but without passengers in the train. This situation occurs frequently, for example when the train is waiting between two commercial runs.

— **Parking mode:**

A train is in parking mode when it is stationary in depots, with the power supply active, without staff or passengers being on board. Usually, the HVAC system runs with reduced settings for temperature and airflow.

Other train modes such as empty carriage stock movements are not considered in this standard as they do not contribute significantly to the annual energy consumption.

In this standard the preconditioning (pre-heating or pre-cooling) and cleaning are not considered separately. The corresponding hours shall be counted in the in-service without commercial operation mode.

The train is switched OFF for remaining time of each day, therefore without any energy consumption.

To keep different characteristics, requirements and procedures manageable, the energy consumption of the whole train is subdivided into the following three different energy categories, which are handled separately:

1) Traction and Auxiliaries (in-service with commercial operation mode, without HVAC);

2) Traction and Auxiliaries (in-service without commercial operation mode and in parking mode, without HVAC);

3) HVAC.

This document incorporates infrastructure and operational conditions into “service profiles” for the train. The service profile for traction and auxiliaries is assessed via train runs along a line for in service with commercial operation and stationary at the depot for in service without commercial operation. HVAC is assessed via an operational point matrix for different operational modes.

The energy consumption over such service profiles shall be used as an input when assessing LCC. This requires a well-defined and harmonized methodology for specification and verification of the energy consumption. The selected approach has two steps:

a) simulation of the energy consumption of the train for the three energy categories mentioned above;

b) verification of the simulation by undertaking measurements.

It is important to note that two different types of service profiles for traction and auxiliaries may be chosen:

4) user-defined service profiles based on data from a real railway line, normally one or several lines of the railway network where the train will be operated;

5) standard service profiles, for the following categories:

   — suburban (passenger service);

   — regional (passenger service);

   — intercity (passenger service);

   — high speed (passenger service);

   — freight mainline service;

   — metro (passenger service).

Definitions of relevant parameters for the user-defined (1) and standard (2) service profiles are set out in Annex A. Annex B describes the standard profiles. The standard service profiles are characterized by definitions of standard values for the identified service types being typical (that is representative) – yet not real – of the type of railway service.

This means that it may not be possible to validate these on a real world track unless some adjustments of the verification results are undertaken to take into account the differences between the simulation and verification. However, these standard service profiles are intended to be a common basis against which different trains can be simulated and simulation results compared.

For the assessment of HVAC energy consumption, standard weighting factors for the operational points are set out in Annex C.

5 Traction and Auxiliaries (with commercial operation, without HVAC)

5.1 General

This clause is focused on traction energy in-service mode on a single train run for a train travelling from origin to destination location including standstill times on the way using the representative driving cycles. It includes energy related to traction auxiliaries (control, cooling and leading driver's cab HVAC which is necessary for safe train driving) and other in commercial operation usually activated on-board systems in normal operating mode.

It excludes energy related to HVAC for the passenger saloon and for the inactive driver's cab, auxiliary equipment rarely used is also expressly omitted (for example windscreen wiper, sanding, defrosters).

For the traction and auxiliary energy in service, the defined timetable for the operation over a specified line plays an important role. This document is therefore not a direct specification of detailed driving styles, instead it provides a framework which allows freedom for the user to propose sound solutions integrating a given mix of energy efficient technologies and driving styles.

5.2 Operational requirements

5.2.1 General

The information in this subclause is applicable for both simulation and verification of energy consumption. The definitions of relevant parameters are given in Annex A. Each parameter is identified by a letter followed by two digits.

5.2.2 Train data

5.2.2.1 Train and traction equipment

The analysis of energy consumption shall include the train and its mechanical losses, the traction chain (electric, diesel-electric or diesel-mechanic) and all auxiliaries which are essential to operate the traction chain including control circuits for traction and signalling.

5.2.2.2 Load conditions

EN 15663:2017+A1:2018 shall be read in conjunction with this subclause.

The gross mass, and therefore the load, of a train has a significant influence on its energy consumption. The mass of the train shall be specified as set out in this clause based on the train category:

a) Passenger trains:

   The train mass (ID S05) is based upon design mass in working order plus the mass of 50 % of seated passengers set out in EN 15663:2017+A1:2018.

b) Freight trains:

   The train mass consists of the locomotive mass which is based upon the design mass in working order plus a trailing consist, which shall be homogeneous, i.e. shall consist of only one wagon or coach type. The following values shall be specified for the trailing consist as a load:

   1) total mass of the trailing consist [t] (ID S06);

   2) rotating masses in terms of equivalent mass [t] (ID S07);

   3) length of the trailing consist [m] (ID S08);

   4) running resistance [kN] of the trailing consist versus speed [km/h] over the whole speed range (ID S09).

The parameters used to characterize load conditions are set out in Table A.4.

5.2.3 Infrastructure conditions

5.2.3.1 Longitudinal profile

The longitudinal profile shall be defined by the following parameters:

1) total distance of selected route or reference track from selected origin location to selected destination location [km] (ID I01);

2) height [m], as an absolute value (above sea level) (ID I02);

3) gradient [‰], as difference in height divided by difference of distance in longitudinal direction (ID I03).

ID I02 and ID I03 are correlated. It shall be checked and documented that the integral of gradients along the track results in the correct difference of height between origin and destination location.

The parameters used to characterize the longitudinal profile are set out in Table A.2.

5.2.3.2 Maximum speed profile

The maximum speed profile [km/h] shall be defined by the following parameters: maximum speed profile at every location along the selected route or reference track (ID I04).

The speed profile shall include the following criteria:

1) maximum speed for which the line, relevant to the profile, is planned;

2) permanent speed reductions due to curves, defined by the required capabilities of the specified train:

   For example, tilting trains may have a higher permitted speed in some sections along the route than other trains;

3) non-permanent speed reductions due to signalling, defined by conditions during verification runs or service operation of the train:

   For example, speed restrictions imposed by the changeover between two tracks shall already be included in the speed profile;

4) rules for safe operation:

   For example, if the operation rules require the target speed to be reached 100 m before a permanent speed restriction, this shall be included in the profile.

The parameters used to characterize speed profile are set out in Table A.2.

5.2.3.3 Curves

The curves shall be defined by the following parameters: location and radius of each curve along the selected route or reference track [m] (ID I05). Transitions can be simplified as step-functions.

The parameters used to characterize curves are set out in Table A.2.

5.2.3.4 Tunnels

The tunnels shall be defined by the following parameters:

— location and length [m] of each tunnel along the selected route or reference track (ID I06);

— location and cross sectional area [m^2] of each tunnel along the selected route or reference track (ID I07).

Short tunnels with a length of less than 20 m and road bridges over the railway are negligible.

The parameters used to characterize tunnels are set out in Table A.2.

In addition, the tunnel surface and ventilation shafts or cross vents may have a significant impact on tunnel drag and thus energy consumption in case of long tunnels, these data should be provided as well.

5.2.4 Timetable and driving style

5.2.4.1 Timetable

A single-train run shall be specified. The sensitivity of energy consumption versus travelling time is high. Therefore, the requirements on precision of the timetable are high as well.

The timetable shall be defined by the following parameters:

— Timing points:

  the number and exact location of all planned stops (origin location, destination location and intermediate stops) and passing points (if applicable) (ID S01).

— Standstill times on the route:

  the time duration elapsed for stopping at scheduled stops (wheels not in motion), during the run over the specified profile (ID S02).

  — Standstill time shall be given for each planned intermediate stop. Otherwise the timing point is considered to be a passing point (without stop).

  — Standstill times at the origin location or destination location of the train run shall be given only if they are considered as part of the train run.

— Departure, arrival and passing times:

  Required timings for departures (time at which the wheels begin to roll), arrivals (time at which the wheels stop) and passing (time at which the rear of the train has passed the point) along the train run (ID S03).

  — All these times shall be given as total time elapsed since departure from the origin location, that is duration including all running and standstill times between origin and the respective timing point.

  — It is required to specify the arrival time at the last stop, that is the journey duration as total time elapsed (from wheels rolling at origin location to wheels stopped at destination location).

  — It is not mandatory to define the arrival and departure time for each intermediate stop. An optimization of the train run over more than one stop-to-stop section is possible in such cases.

  — For passing points (optional) an earliest passing time, or a latest passing time, or both, in order to avoid conflicts with other trains, may be defined. If an earliest passing time as well as a latest passing time are specified, they shall have a minimum difference of 30 s.

— Minimum speed (optional). Minimum cruising speed over a particular section between two locations (for operational constraints, in order to guarantee the capacity of the line) (ID S04).

All times shall be specified in (hh:mm:ss) format.