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Specification and verification of energy consumption for railway rolling stock

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

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TECHNICAL SPECIFICATION

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Specification and verification of energy consumption for railway rolling stock

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

Spezifikation und Überprüfung des Energieverbrauchs von Schienenfahrzeugen

This Technical Specification was approved by CENELEC on 2013-11-05.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B - 1000 Brussels

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Foreword

This document (CLC/TS 50591:2013) has been prepared by CLC/TC 9X/WG 11, "Energy Measurement on-board trains", of CLC/TC 9X "Electrical and electronic applications for railways".

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1 Scope

This Technical Specification 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 pantograph or from the fuel tank, over a predefined service profile, in order to assure that the results are directly comparable or representative of the real operation of the train. For this purpose this document takes into account the energy consumed and regenerated by the rolling stock.

This Technical Specification provides the framework which gives guidance on the generation 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 Technical Specification does not cover specification for comparison of energy consumption with other modes of transportation, or even for comparison between diesel and electric traction, dealing only with the energy consumption of the Railway rolling stock itself. Consequently, this document is not applicable to the evaluation of the carbon foot print of the railway transportation system.

2 Normative references

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

EN 590, *Automotive fuels — Diesel — Requirements and test methods*

EN 13129-2, *Railway applications — Air conditioning for main line rolling stock — Part 2 : Type tests*

EN 15663:2009, *Railway applications — Definition of vehicle reference masses*

EN 50163, *Railway applications — Supply voltages of traction systems*

EN 50463 (all parts), *Railway applications — Energy measurement on board trains*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

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 specification in order to facilitate understanding. Expression of the performance of electrical and electronic measuring equipment has been taken from EN 60359.

3.1.1
auxiliaries
equipment needed to operate the traction equipment, but not producing tractive or dynamic braking efforts themselves (e.g. cooling fans, oil and water pumps, and compressor)

Note 1 to entry: In the context of this Technical Specification, heating and/or air conditioning of the leading driver's cab is included in the auxiliaries.

3.1.2
comfort systems
all equipment consuming energy, belonging neither to the traction equipment nor to its auxiliaries, mainly in passenger cars (e.g. lighting, heating, air conditioning, toilets, information and entertainment systems, laptop supplies)

3.1.3
consist
group of vehicles which are not separated during normal operation or a single vehicle

3.1.4
contact line
CL
conductor system for supplying electric energy to a traction unit through current-collecting equipment

[SOURCE: IEC 60050-811:1991, 811-33-01, modified]

3.1.5
diesel multiple unit:
DMU
train having a fixed composition powered by one or several diesel engines having a fixed composition

3.1.6
electric traction system
railway electrical distribution network used to provide energy for rolling stock

Note 1 to entry: The system may comprise:

– contact line systems,

– return circuit of electric traction systems,

– running rails of non-electric traction systems, which are in the vicinity of, and conductively connected to the running rails of an electric traction system,

– electrical installations, which are supplied from contact lines either directly or via a transformer,

– electrical installations in power plants and substations, which are utilized solely for generation and distribution of power directly to the contact line,

– electrical installations of switching stations.

3.1.7
electric multiple unit
EMU
train having a fixed composition and getting its traction power from an external Electric traction system

3.1.8
heating, ventilation and air conditioning
HVAC
system to help maintain good indoor air quality through adequate ventilation with filtration and provide thermal comfort

3.1.9
infrastructure
fixed installations of the railway system (e.g. tracks, power supply, signalling, communication)

3.1.10
net energy
difference between the energy taken (consumed) from the Contact Line by the traction unit and the energy fed back (regenerated) into the Contact Line by the traction unit

3.1.11
rolling stock
general term covering all railway vehicles or consist of vehicles

Note 1 to entry: Rolling stock may be fitted with traction equipment.

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 exploitation of the train

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

3.1.14
railway system simulation
simulation of several trains over one or several parts of infrastructure (railway network), including effects of train performance, power supply characteristics, operational constraints (time table, conflicts between trains)

3.1.15
traction equipment
equipment directly needed to produce tractive or dynamic braking effort (e.g. transformer, converters, motors, gearboxes)

3.1.16
traction unit
railway vehicle or a fixed composition of vehicles with traction ability (e.g. locomotive, multiple traction unit)

3.1.17
train
consist ready for use, capable either of in-service operational mode or of out of service mode (pre-heating and pre-cooling, cleaning and parking)

3.1.18
vehicle
smallest part in a train, intended as a single vehicle (e.g. freight wagons, passenger coaches, locomotives)

3.2 Abbreviations

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

All the abbreviations are listed in alphabetical order:

a.c.	Alternating Current
d.c.	Direct Current
DMU	Diesel Multiple Unit
EMU	Electric Multiple Unit
HVAC	Heating, Ventilation and Air Conditioning
LCC	Life Cycle Cost

4 General

Energy is an integral quantity. This means that the cumulated energy is the decisive factor. Realistic train operation always has to take place under the constraints of infrastructure and operational requirements. The defined timetable for the operation over a specified line plays an important role. This Technical Specification incorporates these conditions into a so-called “service profile” for the train.

This Technical Specification is therefore not a direct specification of detailed operational profiles and 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.

The energy consumption over such a service profile can be used as an input when assessing LCC. It can also serve as key documentation for the environmental performance of the train. This requires a well defined and harmonised methodology for specification and verification of the energy consumption. The selected approach has two steps:

1) simulation of the energy consumption of the train, over one or more simulation train runs;

2) verification of the simulation by undertaking test train runs.

Two different sorts of service profiles may be chosen:

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

b) standardised, service profiles, for the following categories for passenger service:

- suburban;
- regional;
- intercity (inter-regional);
- high speed;

and for the following types of freight service:

- mainline;
- shunting.

Definitions of relevant values for the typical service profiles and their parameters are given in annex B of this Technical Specification. The standard service profiles are characterised by definitions of standard values for the identified service types being typical (i.e. 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 is undertaken to take account of the differences between the simulation and verification. However, these standardised service profiles are intended to be a common basis against which various trains can be simulated and simulation results compared.

In order to keep different characteristics, requirement and procedures manageable, the energy consumption of the whole train is subdivided into different aspects and handled separately:

- Traction equipment and auxiliaries necessary for traction without comfort systems;
- Only comfort systems (for all operating modes).

The following clauses show how to define the infrastructure (clause 5) and the operational and environmental conditions (Clause 6) for both simulations and verification tests. The simulations are specified in Clause 7 and verification tests in Clause 8. Finally post processing of test results is described in Clause 9.

5 Infrastructure description

5.1 General

The infrastructure shall be defined by the characteristics as specified in the following clauses. All values shall be given as a function of the distance (running path of the train).

The recommended resolution of position for track parameter changes (gradient, speed limit, curve radius, tunnel cross section) in longitudinal direction is one meter.

5.2 Longitudinal profile

The longitudinal profile shall be defined by the following required parameters:

- total distance of selected route or reference track from selected origin station to selected destination station [km] (ID I01, this identification number refers to the infrastructure parameter 01 in Annex A),
- height [m], as an absolute (above sea level) or relative value e.g. versus height of the start station (ID I02),

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

ID I02 and ID I03 are correlated. Gradients may be omitted. If listed, it shall be checked that the integral of gradients along the track result in the correct difference of height between start and terminal station

5.3 Speed profile

The speed profile in [km/h] is defined by the required parameter: maximum speed profile at every location along the selected route or reference track (ID I04). The speed profile shall include the following criteria:

- Maximum speed for which the line, relevant to the profile, is planned.
- Permanent speed reductions due to curves, according to the required capabilities of the specified train. Example: tilting trains may have a higher permitted speed in some sections along the route than other trains.
- Non-permanent speed reductions due to signalling, according to conditions during verification runs or service operation of the train. Example: speed restrictions imposed by the changeover between two tracks shall be either specially marked, or already be included in the speed profile.
- Rules for safe operation. 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.

5.4 Curves

The following parameters shall be specified for curves: location and radius of each curve along the selected route or reference track [m] (ID I05).

Curves with a radius of more than 1 000 m are negligible.

5.5 Tunnels

The following parameters shall be specified for tunnels:

- Location and length [m] of each tunnel along the selected route or reference track (ID I06).
- Location and cross section area [m^2] of each tunnel along the selected route or reference track (ID I07). Very short tunnels with a length of less than 20 m and road bridges over the railway are negligible. Road bridges over the railway are considered as short tunnels with a length of less than 20 m.

5.6 Electric traction system

In case of electric trains, the following characteristics of the Electric traction system shall be defined by the required following parameters:

- nominal voltage (ID E01) and nominal frequency in case of a.c. (ID E02), according to EN 50163;
- mean voltage at the contact line (e.g pantograph) during operation of the train (ID E03), according to experience (measurements) in existing infrastructures, or as a result of total system simulations (for new infrastructure);

  NOTE The mean voltage at pantograph is normally not identical to the nominal voltage.

- position and length of neutral sections or phase separation sections (if applicable) along the selected route or reference track, which require the traction power to be cut (ID E04).

The parameters used to characterise the Electric traction system are defined in Table A.2.

5.7 Diesel fuel oil specifications

In case of diesel trains, the characteristics of the diesel fuel oil shall be defined according to EN 590.

6 Operational requirements

6.1 General

Two main phases during operation of a train are considered here:

- In service operation mode from origin to destination station including stand stills on the way and, if applicable, including HVAC. See 6.2.
- Out of service mode (e.g. pre-heating/pre-cooling, cleaning and parking/hibernate). See 6.3.

6.2 In-service operation mode

6.2.1 Train and propulsion system

A single-train run shall be specified. The specification shall include the train and its mechanical losses, the propulsion chain (electric, diesel-electric or diesel-mechanic) and all auxiliaries which are essential to operate the propulsion chain including control circuits for traction and signalling. Heating and/or air conditioning of the leading driver's cab is considered as part of the traction auxiliaries (to simplify the process for locomotives and during testing).

6.2.2 Timetable

The sensitivity of energy consumption versus travelling time is high. Therefore, the requirements on precision of the timetable are high as well.

The following required parameters shall be specified for the in-service operation mode:

- Stops/stations: The number and exact location of stations with planned stops (except departure and arrival station) (ID S01).
- Standstill time on the route. This is the total time elapsed for stopping times [s] at stations (wheels not in motion), during the run over the specified profile (ID S02). The train is fully operational, but e.g. with reduced auxiliary consumption (ventilation) and/or losses (traction converters blocked).
- Journey duration as total time elapsed (from wheels rolling at departure station to wheels stopped at arrival station) e.g. from time table (ID S03). The specification shall include the required time [s] between each start and stop, for a train run over the profile defined in Clause 5. During both simulation and verification, these times have to be held with high precision (see 7.2.2).

Journey durations and standstill times shall be specified as an integer number (whole number) of seconds.

6.2.3 Payload

EN 15663:2009 shall be used for reading and understanding of this clause.

The gross mass, and therefore the load, of a train have a significant influence on its energy consumption. The mass of the train shall be specified as follows:

a) Multiple units and passenger coaches, for the selected configuration: design mass [kg] in working order (i.e. dead mass, plus consumables, plus staff) plus normal operational payload or specified load conditions (see below).

b) Locomotives: design mass in working order.

c) A trailer consist as a load shall be homogeneous, i.e. shall consist of only one wagon or coach type with identical load in each . Preferred trailer vehicle types are single-deck or double-deck