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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Railway applications - Braking - Brake performance

Applications ferroviaires - Freins - Performance de freinage

Bahnanwendungen - Bremse - Bremsvermögen

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European foreword

This document (prEN 16834:2025) 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 16834:2019.

prEN 16834:2025 includes the following significant technical changes with respect to EN 16834:2019:

- railbound construction and maintenance machines have been included to the scope;
- normative references have been updated;
- definitions for terms “minimum load” and “normal load” have been deleted;
- definitions for terms “changeover mass” and “maximum design speed” have been added;
- symbols and abbreviations have been revised;
- brake assessment with braked weights has been revised;
- test methods in general and for freight wagons, coaches, EMU/DMU have been revised;
- load conditions for tests have been revised;
- testing speeds have been revised;
- method of the test execution has been revised;
- test in degraded mode and degraded conditions has been revised;
- determination of brake performance for the ETCS system has been deleted;
- evaluation of the test results for stopping distance has been revised;
- stationary brake testing has been revised;
- calculation of the longitudinal jerk during braking has been added;
- assessment for deceleration method has been revised;
- assessment of the braked weight has been revised;
- content of the recommendation for the use of braked weight percentage in operation has been moved to an informative Annex (Annex L);
- assessment of gradient capability of stationary brakes has been revised;
- normative Annex B “Brake assessment for single vehicles” has been revised with addition of speeds at 180 km/h and 200 km/h;
- normative Annex E “Determining the equivalent brake response time” has been revised;

- requirements of informative Annex I “Example for verifying the maximum utilization of adhesion between wheel and rail for non-homogenous friction brake equipment” have been changed to recommendations;
- requirements of informative Annex J “Example for correction and validation of test results exceeding mandatory test conditions — Treatment of curve radii lower than 1 000 m” have been changed to recommendations;
- new Annex K “Examples of correction of the mean stopping distance to nominal state of the brake system” has been added;
- Annex ZA has been deleted;
- bibliography has been updated.

1 Scope

This document defines a harmonized way to assess the braking performance by test of locomotives, passenger coaches, freight wagons, railbound construction and maintenance machines, and self-propelled passenger trains (multiple units) including high speed trains.

The document sets out the standardized method for undertaking brake performance tests and the correction factors to be applied to the data obtained for all types of rolling stock.

This document also defines the methods to assess the brake performance in terms of stopping distance, and from this the process to determine vehicle(s) deceleration and braked weight.

It then deals with conversion of the braked weight to the braked weight percentage of a vehicle or train for operating purposes. It also sets out additional factors when determining the braked weight percentage of a train calculated from specified braked weight, depending on the formation of the train.

In Annex D there is a method for determining brake performance of freight wagons fitted with P10 cast iron or LL-blocks using limited testing (force measurement).

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 14198:2016+A2:2021, *Railway applications — Braking - Requirements for the brake system of trains hauled by locomotives*

EN 14531-1:2015+A1:2018, *Railway applications — Methods for calculation of stopping and slowing distances and immobilization braking - Part 1: General algorithms utilizing mean value calculation for train sets or single vehicles*

EN 14531-2:2015, *Railway applications — Methods for calculation of stopping and slowing distances and immobilization braking - Part 2: Step by step calculations for train sets or single vehicles*

EN 15328:2020+A1:2024, *Railway applications — Braking — Brake pads*

EN 15355:2019+A1:2023, *Railway applications — Braking — Distributor valves and distributor-isolating devices*

EN 15663:2017+A2:2024, *Railway applications — Vehicle reference masses*

EN 15877-1:2024, *Railway applications — Markings of railway vehicles — Part 1: Freight wagons*

EN 16207:2024, *Railway applications — Braking — Functional and performance criteria of magnetic track brake systems for use in railway rolling stock*

EN 16452:2015+A1:2019, *Railway applications — Braking — Brake blocks*

EN ISO 24478:2024, *Railway applications - Braking - General vocabulary (ISO 24478:2023, including corrected version 2024-04)*

ISO 20138-1:2018, *Railway applications — Calculation of braking performance (stopping, slowing and stationary braking) — Part 1: General algorithms utilizing mean value calculation*

ISO 20138-2:2019, *Railway applications — Calculation of braking performance (stopping, slowing and stationary braking) — Part 2: General algorithms utilizing step by step calculation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 24478:2024, EN 14198:2016+A2:2021 and the following apply.

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

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

3.1

brake assessment speed

brake initiation speed which is decisive for determination of brake performance

Note 1 to entry: In general, the initiation speed leading to the lowest braked weight.

3.2

braked weight

representative quantity for the mean braking capacity of the vehicle or train, expressed in tons, which is always expressed as a whole number

Note 1 to entry: It is displayed on the vehicle (in accordance with EN 15877-1:2024 and EN 15877-2:—²). Braked weight corresponds to the retardation effort and is currently expressed and designated as “B”.

3.3

braked weight percentage

quotient of braked weight and vehicle mass $\times 100$

Note 1 to entry: Also known as λ (lambda).

3.4

maximum braking load

MXB

load condition lower or equal to “design mass under exceptional payload” (MXD) as defined in EN 15663:2017+A2:2024 in accordance with the related vehicle standard (e.g. EN 16185-1, EN 14198:2016+A2:2021, EN 15734-1)

3.5

fully certified and exchangeable LL-block

LL-block, which fulfils all UIC requirements including exchangeability with P10 (as listed in ERA document ERA/TD/2009-02/INT)

3.6

K-block

brake block with “K”-friction materials as defined in EN 16452:2015+A1:2019

3.7

EN-UIC brake

brake system as defined in EN 14198:2016+A2:2021

3.8

changeover mass

lowest value of vehicle mass at which it is deemed to be in the loaded state, thereby requiring the adjustment of brake force to achieve the required brake performance

[SOURCE: EN 15624:2021+A1:2024, 3.4]

3.9

maximum design speed

maximum speed for which the vehicle is designed to run in operation

Note 1 to entry: This includes all operational modes, e.g. working mode and running mode for railbound construction and maintenance machines.

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in Table 1 apply.

Table1 — Symbols and abbreviated terms

Symbol/ abbreviated term	Description	Unit
a	deceleration	m/s ²
B	braked weight	t
$B_{R, red}$	braked weight in brake position “R” with brake pipe accelerator active. The index “red” refers to the colour of marking.	t
C	constant for calculating the λ values	—
D	constant for calculating the λ values	—
d	diameter	mm
F	force	kN
g	acceleration due to gravity	9,81 m/s ²
i	gradient	‰
k	assessment factor for determining the braked weight (in Annex D)	—
k_h	reduction factor for the influence of humidity (reduced friction coefficient)	—
k_w	reduction factor for the influence of wet rail (reduced adhesion)	—
m	mass of the test train or test vehicle	t
r	radius	mm
s	total stopping distance (up to $v = 0$)	m
t	time	s
v	speed	km/h
v_{max}	maximum design speed	km/h

Symbol/ abbreviated term	Description	Unit
w_{Bo}	mean curve resistance	‰
λ	braked weight percentage	%
ρ	coefficient of inertia of rotating masses	—
σ_n	standard deviation of test result	m
τ	adhesion	—
μ	coefficient of friction	—
η	efficiency of brake rigging	—
ATP	automatic train protection	—
Bg	brake block type Bg (single block)	—
Bgu	brake block type Bgu (double brake block)	—
ECB	eddy current brake	—
EP brake	electro-pneumatic brake	—
ETCS	European Train Control System	—
G	brake mode of the slow-acting brake (freight train)	—
K	brake block material in accordance with EN 16452:2015+A1:2019	—
L	brake block material in accordance with EN 16452:2015+A1:2019	—
LL	brake block material in accordance with EN 16452:2015+A1:2019	—
MVD, MNO, MND, MXD	load cases in accordance with EN 15663:2017+A2:2024	—
MXB	maximum braking load in accordance with 3.4	—
MTB	magnetic track brake	—
P	brake position of quick-acting brake (passenger train)	—
P+E	brake position P + electrodynamic brake	—
P+H	brake position P + hydrodynamic brake	—
P+Mg	brake position P + magnetic track brake	—
P+X	placeholder for any combination of P and additional brakes (e.g. P+E, P+Mg, ...)	—
P10	material designation of the cast-iron block with a 1 % phosphorus content	—
R	brake position R or <R> in accordance with EN 14198:2016+A2:2021	—
R+E	brake position R + electrodynamic brake	—
R+H	brake position R + hydrodynamic brake	—

Symbol/ abbreviated term	Description	Unit
R+X	placeholder for any combination of R and additional brakes (e.g. R+E, R+Mg etc.)	—
S	train related brake performance category in accordance with EN 14198:2016+A2:2021	—
SS	train related brake performance category in accordance with EN 14198:2016+A2:2021	—
Wb	eddy current brake	—

5 Principles of determining the brake performance

5.1 General

The object of defining the brake performance of railway brakes is to characterize the braking capabilities of railway vehicles.

To determine the brake performance three methods of brake assessment can be used: stopping distance, braked weights, and deceleration. All three will determine the brake performance.

From vehicle testing, braked weight is derived from stopping distance. For freight wagons (fitted with cast iron blocks or fully certified and exchangeable LL-blocks) the braked weight can be calculated as set out in Annex D, if applicable.

Brake performance assessment is specified based on a number of standardized conditions (e.g. level track, dry rail and mean in-service vehicle condition). Brake assessment thus does not assume the worst possible vehicle condition, which can be the result of e.g. braking force tolerances, friction coefficient scatter, downgraded efficiency, or the failure of brake system components etc.

These brake performances do not contain safety margins.

For vehicle having different brake positions as described in EN 14198:2016+A2:2021, there shall be an assessment for each brake position.

The brake performance marked on vehicles (EN 15877-1:2024 and EN 15877-2:—²) shall be derived from the performance determined by tests and/or calculation according to this document.

Links between calculation of brake performance and test are given in Table 2.

Table 2 — Links between calculation of brake performance and test

Vehicle type	Calculation	Brake performance	Validation by test
All vehicles excluding freight wagons	EN 14531-1:2015+A1:2018/ISO 20138-1:2018 and/or EN 14531-2:2015/ISO 20138-2:2019	Decelerations + response time/stopping distance ↑ ↓ Braked weights	All vehicles excluding freight wagons
Freight wagons	EN 14531-1:2015+A1:2018/ ISO 20138-1:2018 and/or EN 14531-2:2015/ISO 20138-2:2019 or Annex D, if applicable (cast iron/certified LL-blocks)	Stopping distance ↑ ↓ Braked weights	Mandatory ^a
^a With exception of freight wagons, where the requirements of Annex D are met.			

5.2 Brake assessment with braked weights

This method originated after the introduction of the compressed air brake. For this purpose, a huge number of test runs on level track had been performed with a given passenger train with 60 wheelsets, specified brake equipment and given mass from various initial speeds.

The brake performance of this train has been ever since equivalent to $\lambda = 100\%$ and serves as reference standard deceleration so that per definition the braked weight is equivalent to the mass of the train. The results of further tests with different brake settings set up brake assessment charts providing the relations:

$$\lambda = f(v, s) \quad (1)$$

where

- s is the stopping distance, expressed in m;
- v is the initial speed, expressed in km/h;
- λ is the brake weight percentage, expressed in %.

The reference train was equipped with block brakes with low-phosphorus cast-iron blocks.

A **brake assessment diagram** is used as a basis of reference for determining the brake performance of new vehicles using the passenger brake mode.

The assessment diagrams (see Figure A.1 and Figure B.1) are applicable for an initial braking speed of up to 200 km/h.

The braked weight is expressed in tons. The quotient obtained from the sum of all the braked weights and the mass of the train multiplied by 100 gives the braked weight percentage λ of the train and relates to the stopping distance in the event of an emergency brake application.

The braked weights assigned to the individual vehicles or vehicle segments are normally to be marked on the outside of the vehicles in accordance with EN 15877-1:2024 and EN 15877-2:—² when they are obtained from brake application by brake pipe only. Braked weights shall be indicated in whole numbers of tons, with values $< 0,5$ to be rounded down and values $\geq 0,5$ to be rounded up. If the results come from

tests on a train, the figures are initially rounded up or down for the smallest unit (wagon) on which a braked weight is indicated.

The braked weight marked on a vehicle shall indicate the brake performance of this vehicle in a 400 m (passenger trains) or 500 m (freight trains) long rake braked in the P brake mode (including brake positions P+X, R, R+X). The definition of braked weights and brake weight percentage used for this purpose requires an EN-UIC brake with filling time of the brake cylinder and transmission time of the main brake pipe as specified in EN 15355:2019+A1:2023 for the “passenger train” brake mode. Whenever deviating from these parameters, the influence shall be evaluated and compensated by suitable measures.

The braked weight of a train is equivalent to the sum of the braked weights marked on the individual vehicles with active brakes.

Some recommendations for operating rules are presented in Annex L.

5.3 Brake assessment with deceleration's method

The brake performance of trains can be expressed by decelerations. This method may be applied for all speed ranges. For speeds over 200 km/h, it is mandatory.

The real train deceleration profile is approximated by a function with equivalent brake response time and one or more speed intervals of constant decelerations.

The deceleration method set out in this document is intended to describe the train deceleration in a simplified set of values and not by the individual braking functions.

6 Execution of tests

6.1 Test methods

6.1.1 General

6.1.1.1 Test institute

The tests shall be performed by a competent authority.

NOTE As an example, a test institute in accordance with EN ISO/IEC 17025.

6.1.1.2 Measurement uncertainty

Any limit values for e.g. stopping distances, deceleration, brake weights or adhesion values are valid for mean vehicle conditions and can deviate to both sides in operation.

For that reason, no extra margin for covering the measuring uncertainty shall be taken when checking limit values.

NOTE The measuring methods (equipment and processing) used today generally have the capability of achieving a measuring uncertainty at least as good as those in use, when the limit values for the vehicle assessment were established.

6.1.1.3 Train testing/single vehicle testing

Train testing is the original method, which gives more accurate results and is always applicable. In the following cases, the train test can be replaced by single vehicle test, which leads to more restrictive results:

- for coaches with maximum speed ≤ 200 km/h;
- for freight wagons;

- for locomotives;
- for single multiple units (as specified in EN 16185-2).

6.1.2 Freight wagons and coaches

If the braked weight of freight wagons/coaches is determined by testing with a train, the following special conditions apply:

- coaches: for the purpose of the tests a 400 m long hauled train should be used comprising identical coaches with the same brake equipment;
- freight wagons: for the purpose of the tests a 500 m long hauled train should be used comprising identical freight wagons with the same brake equipment;
- in both cases the locomotive brake shall be isolated and all brake pipe accelerators and the EP assist shall be deactivated.
- for freight wagons and coaches equipped with brake pipe accelerators tests shall be performed with brake pipe accelerators activated or deactivated depending on the brake position to be assessed, e.g.
 - P, R brake pipe accelerator deactivated;
 - R_{red}: brake pipe accelerator activated;
 - R+X_{red}: brake pipe accelerator activated.

If the braked weight of freight wagons is determined by testing with a single vehicle, the following conditions for the composition of test objects to be uncoupled apply:

- one wagon in the case of basic bogie wagons;
- a set of three wagons in the case of two-axled vehicles;
- a set of two wagons in the case of articulated wagons with single axles;
- a set of wagons which cannot be split in service.¹

6.1.3 Locomotives

When determining the braked weight of the locomotive in position G, tests from 100 km/h in position P shall be undertaken with the locomotive operating on its own. For all other brake positions, the testing shall be done as set out in 6.3.

Locomotives with multiple brake control architecture shall be tested in all operating modes (e.g.: UIC brake pipe, direct EP brake, rescue- or towing-mode, etc.).

6.1.4 Multiple units and high speed trainsets

The brake performance of a multiple unit is determined by dynamic tests for all existing brake positions with all brakes active. To determine the brake performance in degraded modes dynamic tests shall be

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performed for all relevant cases (e.g. isolated parts of air brake, EP assist, dynamic brake, magnetic track brake).

For multiple units which can be coupled together to operate in multiple working, the tests shall be conducted in the most unfavourable train configuration (considering the equivalent brake response time in Annex E) determined by the static test (i.e. generally the longest planned formation).

Multiple units and highspeed trainsets with multiple brake control architecture shall be tested in all operating modes (e.g. UIC brake pipe, direct EP brake, rescue- or towing-mode).

6.1.5 Testing of vehicles/trains with additional brake equipment

Typically, additional brake equipment for service and/or emergency brake applications include

- dynamic brake;
- eddy current brake;
- EP assist;
- magnetic track brake;
- brake pipe accelerators.

The testing specified in 6.1.4 shall be undertaken with all brake equipment operational.

If additional brake equipment is used in emergency brake or service brake, additional testing should be performed to determine brake performance with this equipment isolated.

If more than one additional equipment is fitted, there should be further testing to determine the contribution of each equipment.

6.2 Load conditions for tests

6.2.1 Freight wagons

For freight wagons with empty-loaded changeover devices, slip tests shall be conducted:

- in load case MVD (empty freight wagons), in the “empty” position;
- in the “empty” position with a load at the changeover mass. When an automatic empty-loaded changeover device is being used, the tests shall be carried out in the “empty” position with a load close to the changeover mass, but far enough below it to ensure that the automatic changeover device remains stable in the “empty” position;
- in load case MND in the “loaded” position.

For freight wagons with self-adjusting load-proportional braking, the slip tests shall be conducted:

- in load case MVD;
- in the lowest load case under which the maximum braked weight is achieved;
- at the condition at which the maximum energy is dissipated (combination of speed and load).

For S and SS freight wagons, as defined in EN 14198:2016+A2:2021, the load definition leads to Table 3.

Table 3 — Load conditions for slip tests with S and SS freight wagons

Vehicle mass	S-wagon with empty-loaded changeover device	S-wagon with self-adjusting load-proportional (S2 in EN 14198:2016+A2:2021)	SS-wagon
MVD	X	X	X
Changeover mass	X		
14,5 t/wheelset		X	
18 t/wheelset			X
20 t/wheelset			X
22,5 t/ wheelset	X	X	
X Mandatory tests			
NOTE The values of the vehicle weight are typical values for S- or SS-wagons with tread-braked wheels.			

6.2.2 Locomotives

For locomotives only MVD shall be tested.

6.2.3 Passenger vehicles

Load condition for passenger vehicles is specified in Table 4.

Table 4 — Load conditions for testing

Vehicle type	Load status		
	MVD	MND	MXB
Coach, passenger trains, multiple unit and high speed train without load compensating brake systems	X	X ^a	X
Coach, passenger trains, multiple unit and high speed train with load compensating brake systems	X	X ^b	X
X Requirement			
^a It is allowed to eliminate the tests in load case MND if the difference between MND and MXB is less than 10 % of MND. If the difference is higher than 10 % it is allowed to perform the tests at MND only at maximum speed and one intermediate speed. ^b It is allowed to eliminate the tests in load case MND if the load compensation covers the whole range from MVD to MXB and if the difference between MND and MXB is less than 10 % of MND.			

In cases where loading is not possible, alternative methods are permitted, such as simulation by isolating other brake units, as long as this introduces no significant errors into the procedure. In particular, it shall be observed on vehicles with self-adjusting load-proportional braking that the correct brake cylinder pressures (corresponding to the load) are adjusted by means of the simulated load condition.

Simulation is performed as follows:

The number of isolated brakes is determined in accordance with Formula (2) such that the ratio of:

$$\frac{\sum \text{the active brake forces}}{\sum \text{the installed brake forces}} = \frac{\text{dynamic mass of test train}}{\text{dynamic mass of laden train}} \quad (2)$$

is generally complied with.

The simulation is only allowed for long trains (400 m excluding the locomotive) not for single vehicles, multiple units and high speed train.

6.3 Speeds to be used for testing

6.3.1 General

At least four valid braking test results (see 6.4.4) shall be used for each initial speed and for

- emergency brake in each brake position (e.g. R, Rep, R+X, towing case),
- emergency brake in the degraded mode in case of single point(s) failure(s) leading to the longest stopping distance,
- full service brake.

Combinations of speed and brake position, which are not applicable for operation, are not mandatory for testing.

Tests in brake position G are not required (see 8.5 and 8.6).

NOTE Wagons equipped only with G mode are not covered by this standard.

6.3.2 Mandatory initial speeds

Tests shall be carried out on dry rails at initial speed equal to maximum design speed and at the following initial speeds (if lower than the maximum design speed): 30 km/h; 100 km/h; 120 km/h; 140 km/h; 160 km/h; 200 km/h; in steps not greater than 40 km/h from 200 km/h to maximum design speed of the unit.

For coaches with only one stage of braking effort and maximum speed between 160 km/h and 200 km/h (limitations of brake equipment and special evaluations rules: see braked weight assessment 8.3) single vehicle tests can be avoided at initial speed higher than 160 km/h using the optional method described in 8.3.

6.3.3 Recommendation for additional initial speeds

For trains assessed in accordance with Gamma braking model ("Gamma-Train") additional test speeds are recommended:

- An additional test should be done for an initial speed equal to the maximum train design speed + overspeed (e.g. as defined in SUBSET-026-3, 3.13.9.2.3).
- If there is significant change in brake deceleration at specific speeds due to brake system architecture (e.g. maximal speed for MTB application, high/low pressure transition in brake cylinder), then tests for these specific initial speeds should be done. The test speed for this specific case should be chosen close to the system speed in a way that all similar tests show the same behaviour. E.g. in case of an increase of the deceleration at a certain system speed the test speed should be chosen above the system speed in order to have that deceleration change included in all tests.

6.4 Method of execution of the test

6.4.1 General

The test train or test vehicle shall be accelerated up to the speed for the intended brake application. At this speed, the traction is switched off and after that an emergency brake application is initiated on level and straight track. If there are different possibilities to initiate an emergency braking (e.g. by driver brake valve, push-button, ATP valves) the possibility leading to the longest response time shall be chosen for tests used for brake performance assessment. The choice shall be validated by suitable tests.

For single vehicle testing the method of slip test applies. The vehicle shall be uncoupled after reaching the test speed and the emergency brake shall be applied at the same time or short time after uncoupling.

In every test the stopping distance is measured from the point at which the emergency brake application was initiated (e.g. leaving running position of brake controller or emergency button depressed) until the standstill.

The measured stopping distance includes the distance covered during the delay time and the build-up time of brake equipment.

This test method can similarly be applied for other than emergency brake applications (e.g. maximum service braking).

6.4.2 Atmospheric conditions

In order to prevent adverse atmospheric conditions from affecting the results the tests should be carried out with as little wind as possible and dry rails.

No test in flying snow conditions is allowed.

6.4.3 Condition of brake equipment

6.4.3.1 Wheels

For block-braked vehicles with new or reprofiled wheels, these should have been run in for at least 1 200 km.

6.4.3.2 Friction components

Before the start of the tests the friction components (brake pads/blocks) shall be bedded-in to give at least 85 % contact pattern. If the tests include brake applications in wet conditions, the leading edge of the pad/block shall be bedded-in in the direction of rotation. The bedding-in status shall be documented by means of photos of a useful selection of friction elements.

After the successful bedding-in of the brake pads the brake disc roughness is considered to be appropriate for the subsequent assessment tests.

Bedding-in may take place in service or via specific bedding-in brake applications. In the latter case, the temperature of the friction elements shall be monitored regularly in order to avoid thermal overload. The manufacturer's maximum regular temperature limits for each part of the friction pair shall not be exceeded. Between bedding-in applications, the temperature of brake disc or wheel should be allowed to cool to below 100 °C.

6.4.3.3 Magnetic track brakes

Magnetic track brakes shall be bedded-in on the rail head until a contact pattern of 60 % is achieved and prior to the assessment tests the contact surface of the magnetic track brake shall be conditioned as set out in EN 16207:2024, Clause 10.

6.4.4 Number and validity of individual tests

At least four valid tests shall be carried out from which the mean value shall then be calculated. The determination of the mean value, including statistical criteria, is described in 6.6.2.

- a) The starting temperature of the wheels/brake discs shall be measured on at least four of the wheels/discs subject to the theoretically greatest load. This average temperature should be below 60 °C across the measurement points. The starting temperature shall not exceed 100 °C on any measuring point.
- b) The mean gradient over the stopping distance shall be $|i| < 3 \text{ ‰}$; the maximum gradient on the test section shall not exceed $\pm 5 \text{ ‰}$,
- c) Tests on curve radii $< 1\,000 \text{ m}$ are not permitted.
- d) Station areas and tunnels are preferably avoided.
- e) Deviation of the brake initiation speed from the target speed shall be $|v_{i,\text{meas}} - v_{i,\text{nom}}| \leq 4 \text{ km/h}$. Where the nominal initial speed is higher or equal than 200 km/h, the deviation may increase to 6 km/h. Where the nominal initial speed is lower or equal than 30 km/h, the deviation shall not exceed 2 km/h.
- f) No brake force reduction by WSP system shall occur during dry rail testing.

In the case that any of these testing conditions for brake assessment cannot be fulfilled due to infrastructure restrictions the following measures are required for the individual unit to be assessed:

- determine the influence of those deviations;
- specify a procedure for the correction of the test results;
- validate the correction procedure.

As an example the treatment of curve radii lower than 1 000 m is given in Annex J.

6.5 Test in degraded mode and degraded conditions

If applicable standards for vehicle testing do not make provision for degraded mode and degraded conditions, the following procedure is recommended to cover the degraded mode (failure) and the influence of moisture on wheel/rail adhesion. The influence of moisture on the friction coefficient of mechanical brakes is covered by the assessment method described in 7.4.1 and requires no additional dynamic tests.

- a) degraded mode: braking tests from maximum design speed and at MXB should be performed to measure the performance in degraded mode. The worst possible single failure (leading to longest stopping distance on dry rail) should be simulated by isolation of brakes for each type of brake subsystem:
 - 1) one dynamic brake subsystem isolated;
 - 2) one eddy current subsystem isolated;
 - 3) one magnetic track brake subsystem isolated;
 - 4) one friction brake subsystem isolated (e.g. isolation of distributor);

If a type of brake subsystem depends on a common energy supply, all the subsystems depending on this energy supply should be isolated;

These tests are necessary to calculate the ETCS brake parameters in accordance with EN 17997.

- b) degraded conditions should be simulated by generating low adhesion and tests performed as set out in EN 15595.

6.6 Evaluating the test results for stopping distance

6.6.1 Correcting the stopping distances for each test

The stopping distance obtained in each test “j” shall be corrected in order to take into account the following factors:

- nominal speed in relation to the initial speed measured in the test;
- gradient of the test track.

The correction can be made using Formula (3) or an adapted method taking into account the real track profile (step by step correction of the gradient influence).

$$\frac{v_{j,nom}^2}{2 \times (s_{j,corr} - v_{j,nom} t_{e,j})} = \frac{v_{j,meas}^2}{2 \times (s_{j,meas} - v_{j,meas} t_{e,j})} - \frac{g}{\rho} \times \frac{i'_m}{1000} \quad (3)$$

Conversion gives Formula (4):

$$s_{j,corr} = v_{j,nom} t_{e,j} + \frac{v_{j,nom}^2 (s_{j,meas} - v_{j,meas} t_{e,j})}{v_{j,meas}^2 - \frac{2g i'_m}{1000 \rho} (s_{j,meas} - v_{j,meas} t_{e,j})} \quad (4)$$

with

$$i'_m = i_m + W_{Bo} \quad (5)$$

where

- $s_{j,corr}$ is the corrected stopping distance which corresponds to the nominal speed in the test “j”, expressed in m;
- $s_{j,meas}$ is the stopping distance measured in test “j”, expressed in m;
- $v_{j,nom}$ is the nominal initial speed in test “j”, expressed in m/s;
- $v_{j,meas}$ is the initial speed measured in test “j”, expressed in m/s;
- $t_{e,j}$ is the equivalent response time in test “j” (as defined in Annex E), expressed in s;
- i_m is the mean gradient over s on the test track, with the plus sign for rising gradients and the minus sign for falling gradients, expressed in ‰. For tests on trains, the gradient shall be determined with reference to the train's centre of gravity;
- W_{Bo} is the mean curve resistance over $s_{j,meas}$ of test track. For tests in curves of between 1 000 m and 5 000 m radius, the mean curve resistance shall be calculated using $W_{Bo} = 650/(r - 55)$ N/kN. Above 5 000 m radius, the curve resistance is negligible;
- ρ is the coefficient of inertia of the rotating masses, which is defined in Formula (6);

g is the acceleration due to gravity.

$$\rho = 1 + \frac{m_r}{m} \quad (6)$$

where

m is the mass of the train or test vehicle;

m_r is the equivalent mass of the rotating components.

The adapted method (step by step correction of the gradient influence) is recommended when the gradient profile has significant changes over the stopping distance.

6.6.2 Determining the mean stopping distance

Four or more valid tests shall be conducted in order to determine the mean value. Prior to this, all stopping distances shall be corrected in accordance with the method described in 6.6.1.

For tests with nominal initial speed equal to or higher than 100 km/h (or maximum design speed if lower than 100 km/h) and used to determine brake performance in the sense of the present standard, the test results shall meet the requirements described hereafter.

The mean value shall be considered valid only, if the criteria of Formula (7) and Formula (8) are simultaneously met:

Criterion K1:

$$\frac{\text{standard deviation of test results } (\sigma_n)}{\text{mean value of test results } (\bar{s})} \leq 3,0\% . \quad (7)$$

and Criterion K2:

$$|\text{extreme value } (s_e) - \text{mean value } \bar{s}| \leq 1,95 \times \sigma_n \quad (8)$$

with

$$\sigma_n = \sqrt{\frac{\sum |s_{j,\text{corr}} - \bar{s}|^2}{n}} \quad (9)$$

where

$s_{j,\text{corr}}$ is the stopping distance measured during test “j” and corrected from Formula (4), expressed in m;

$\bar{s}$ is the mean stopping distance, expressed in m;

n number of valid tests;

σ_n standard deviation of test results;

s_e individual stopping distance furthest from mean value.

If after the fourth test one of the two criteria is not met, an additional test shall be conducted and the criteria used again.

If criterion K2 is not met when the number of valid tests ≥ 5 , the extreme value s_e shall be discarded and the criteria reviewed again.

If, however, only K1 is not met or both criteria are not met after the extreme value is discarded, a further additional test shall be conducted.

The procedure shall be applied until K1 and K2 are met or a total of 10 tests have been performed (valid and invalid tests are counted).

The number of valid tests shall be at least 70 % of the number of all the tests performed, bearing in mind that discarded tests due to external factors (wrong test conditions 6.4.4) are not to be counted as part of the overall number of tests performed.

If after a total of 10 tests both criteria are not met, the test series shall be halted and the brake system and test conditions verified. Interruption of the tests shall be noted in the test report.

The flow chart given in Figure 1 demonstrates the correct procedure.

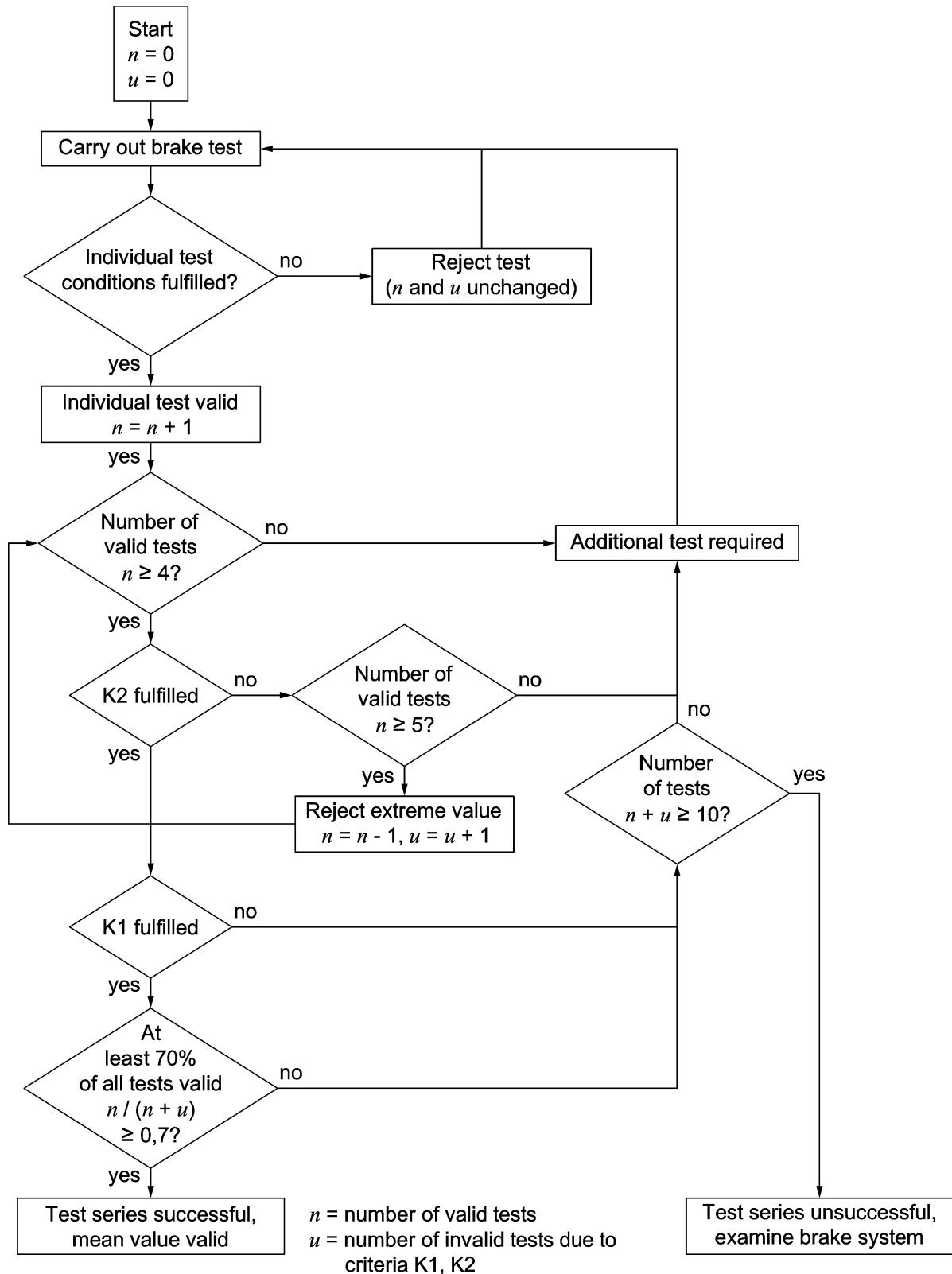


Figure 1 — Procedure of determining the mean stopping distance

6.6.3 Correction of the mean stopping distance to nominal state of the brake system

6.6.3.1 Basic principle

6.6.3.1.1 General

The mean stopping distance $\bar{s}$ is determined as refers to the vehicle in its current condition. To determine brake performance, this result relating to the present condition of the vehicle shall be corrected to a nominal state of the brake system generally applicable to the design series. The following factors are considered in this context:

- Dynamic efficiency of brake rigging on test vehicle in relation to the mean value foreseen for operations. If dynamic brakes are taken into account, the correction factor in relation to brake rigging efficiency is not relevant.
- Influence of the wheel diameter on test vehicle in relation to the nominal value in case of disc-braked vehicles. If dynamic brakes are taken into account, the correction factor in relation to the wheel diameter is applicable if the dynamic braking force is dependent from the wheel diameter.
- In the event that the brake cylinder pressure on the test vehicle deviates from the nominal value assumed for the design series, a correction within a maximum tolerance range of $\pm 0,2$ bar ($\pm 0,1$ bar for freight wagons in tare condition) shall be applied.

The result of the correction $\bar{s}_{\text{corr}}$ shall be mathematically rounded to 1 m.

Depending on the complexity of the brake system several methods of correction are possible:

- simplified method when the deceleration is almost constant over the stopping distance;
- speed-range method when the repartition of the braking force is varying stepwise;
- step-by-step method when the repartition of the braking force is varying continuously.

6.6.3.1.2 Simplified method

Correction with simplified method shall be made using Formula (10) and Formula (11):

$$F_{\text{test}} = \sum_{\text{brake unit } j} F_{\text{test, brake unit } j}$$

$$F_{\text{corr}} = \sum_{\text{brake unit } j} F_{\text{corr, brake unit } j}$$

The factor $\beta_{\text{brake unit } j, \text{ test}}$ is defined as follows:

$$F_{\text{corr, brake unit } j} = F_{\text{test, brake unit } j} \times \beta_{\text{brake unit } j, \text{ test}}$$

$$\alpha_{\text{brake unit } j} = \frac{F_{\text{test, brake unit } j}}{F_{\text{test}}} \approx \frac{F_{\text{brake unit } j, \text{ nom}}}{F_{\text{brake, train, nom}}}$$

$$\rightarrow F_{\text{corr, brake unit } j} = F_{\text{test}} \times \alpha_{\text{brake unit } j} \times \beta_{\text{brake unit } j, \text{ test}}$$

$$F_{\text{corr}} = F_{\text{test}} \times \sum_{\text{brake unit } j} (\alpha_{\text{brake unit } j} \times \beta_{\text{brake unit } j, \text{ test}}) \quad (10)$$

with

$$\alpha_{\text{brake unit } j} = \frac{F_{\text{brake unit } j, \text{nom}}}{F_{\text{brake, train, nom}}} = \frac{F_{\text{brake unit } j, \text{nom}}}{\sum_k [F_{\text{brake unit } k, \text{nom}}]}$$

and

$$\beta_{\text{brake unit } j, \text{test}} = \frac{F_{\text{brake unit } j, \text{corr}}}{F_{\text{brake unit } j, \text{test}}}$$

and

$$\bar{s}_{\text{corr}} = t_e \times v_{\text{nom}} + \frac{F_{\text{test}} + W_m}{F_{\text{corr}} + W_m} \times (\bar{s} - v_{\text{nom}} \times t_e) \quad (11)$$

NOTE For the considered train, $\sum_{\text{brake unit } j} [\alpha_{\text{brake unit } j}] = 1$.

where

$\alpha_{\text{brake unit } j}$	is the weighting factor representing the theoretical part of the brake unit j force in the total braking force;
$\beta_{\text{brake unit } j, \text{test}}$	is the factor representing the ratio of the brake unit j force in nominal (reference) case divided its force during the test
$\bar{s}_{\text{corr}}$	is the corrected mean stopping distance (for nominal state of the brake system), expressed in m;
$\bar{s}$	is the mean stopping distance during test, expressed in m;
t_e	is the equivalent response time, expressed in s;
v_{nom}	is the nominal initial speed during test, expressed in m/s;
F_{corr}	is the corrected mean braking force, expressed in kN;
F_{test}	is the mean braking force at train level during test, expressed in kN;
$F_{\text{corr, brake unit } j}$	is the corrected mean braking force of the brake unit j , expressed in kN;
$F_{\text{test, brake unit } j}$	is the mean braking force of the brake unit j during test, expressed in kN;
$F_{\text{brake unit } j, \text{nom}}$	is the mean braking force of the brake unit j in nominal state (based on brake calculation), expressed in kN;
$F_{\text{brake train, nom}}$	is the mean braking force of the train in nominal state (based on brake calculation), expressed in kN;
W_m	is the mean value of resistance forward movement, expressed in kN.

In the list of symbols “mean braking force” means averaged over stopping distance. For simplification in case of non-speed-dependent α -weighting factor the established braking forces are usually taken instead of mean values.

Response time t_e is defined in Annex E.

For a disk brake unit, the factor β can generally be simplified with Formula (12) as:

$$\beta_{\text{disk brake unit } j, \text{test}} = \frac{\eta_{j, \text{dyn}}}{\eta_{j, \text{dyn, test}}} \times \frac{d_{j, \text{test}}}{d_{j, \text{nom}}} \times \left(\frac{p_{j, \text{nom}} - p_{\text{spring, } j}}{p_{j, \text{test}} - p_{\text{spring, } j}} \right) \quad (12)$$

where

- $d_{j, \text{test}}$ is the mean wheel diameter on test vehicle where brake unit j acts, expressed in mm;
- $d_{j, \text{nom}}$ is the wheel diameter considered in the nominal state of the brake system where brake unit j acts, expressed in mm; for block brakes $d_{\text{nom}} = d_{\text{test}}$;
- $p_{j, \text{nom}}$ is the nominal brake cylinder pressure for brake unit j , expressed in bar;
- $p_{j, \text{test}}$ is the actual brake cylinder pressure during the test for brake unit j , expressed in bar;
- $p_{\text{spring}, j}$ is the equivalent pressure to compensate the force of the retainer spring of brake unit j , expressed in bar;
- $\eta_{j, \text{dyn}}$ is the mean efficiency of brake unit j rigging between two scheduled maintenance activities;
- $d_{j, \text{test}}$ is the mean wheel diameter on test vehicle where brake unit j acts, expressed in mm.

For lambda and braked weight evaluation the nominal wheel diameter d_{nom} shall be the semi worn wheel diameter.

For ETCS gamma train d_{nom} shall be the new wheel diameter.

For other cases d_{nom} is usually the semi worn wheel diameter.

For wagons or coaches with a single central brake cylinder, the formulae can be simplified with Formula (13) as follows:

$$F_{\text{corr, vehicle}} = F_{\text{test, vehicle}} \times \frac{\eta_{\text{dyn}}}{\eta_{\text{dyn, test}}} \times \frac{d_{\text{test}}}{d_{\text{nom}}} \times \left(\frac{p_{\text{nom}} - p_{\text{spring}}}{p_{\text{test}} - p_{\text{spring}}} \right) \quad (13)$$

In order to ensure that new vehicles also deliver the determined braking force, the factor $\frac{\eta_{\text{dyn}}}{\eta_{\text{dyn, test}}} \times \frac{d_{\text{test}}}{d_{\text{nom}}}$ shall be restricted to values ≤ 1 for disc brake units when performing corrections for tests on new vehicles. In the same sense the factor $\frac{d_{\text{test}}}{d_{\text{nom}}}$ shall be restricted to values ≤ 1 for dynamic brake units where the braking force is not adapted automatically to the wheel diameter.

6.6.3.1.3 Speed-range method

This method is the same as in 6.6.3.1.2, but applied on speed ranges, where the theoretical deceleration is considered as constant due to the design of the brake system.

NOTE This method is based on the same philosophy as the ETCS braking model.

6.6.3.1.4 Step-by-step method

This method uses a step-by-step calculation model in accordance with EN 14531-2:2015 or ISO 20138-2:2019.

When applying the test train parameters (e.g. real wheel diameter, brake cylinder pressures, measured efficiency) the step-by-step calculation shall be adapted for each test case (e.g. by adjusting the friction coefficients) to provide the same stopping distance as $\bar{s}$ (see 6.6.2) within a tolerance of 0,3 %.

$\bar{s}_{\text{corr}}$ for the corresponding test case is obtained by using this step-by-step calculation model with nominal train parameters.