



BSI Standards Publication

Railway applications — Braking — Brake pads

National foreword

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European foreword

This document (EN 15328:2020+A1:2024) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2024, and conflicting national standards shall be withdrawn at the latest by October 2024.

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

This document supersedes A1 EN 15328:2020.

EN 15328:2020+A1:2024 includes the following significant technical changes with respect to EN 15328:2020:

- the Introduction has been modified;
- new terms 3.7 “continuous brake application 1” and 3.8 “continuous brake application 2” have been added;
- 5.1. “Classification of brake pads” has been modified;
- 5.13.1 “Classification scheme for locomotives, MUs, high-speed trains, freight wagon and coaches”, Table 5 has been modified;
- 5.14 “Interchangeability of brake pads” has been modified;
- Clause A.9 “Methods of temperature measurements” has been modified;
- Annex B “Test programs for classes A1 to G1”, Tables B.2 to B.11 have been modified;
- Annex C “Test programs for coaches”, Table C.1 has been modified;
- Annex E, E.1 “Use of the generic test programs”, Table E.1, E.2.2 “Brake steps”, E.2.4 “Continuous brake applications”, Table E.5 and E.3.5 “Power for continuous brake applications” have been modified;
- new informative Annex I “Example of the declaration of conformity” has been added;
- Annex ZA has been deleted. A1

This document includes Amendment 1 approved by CEN on 2 March 2024.

The start and finish of text introduced or altered by amendment is indicated in the text by tags A1 A1.

A1 *deleted text* A1

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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Introduction

This document gives the requirements for the design, dimensions, performance and testing of a brake pad which, as part of a disc brake system, acts on one friction face of a brake disc in accordance with EN 14535-1 and EN 14535-2.

 *deleted text* 

This document contains the requirements for interfacing the brake pads with the rail vehicle, the testing procedures in order to confirm that it satisfies the basic safety and technical requirements, the material control procedures to ensure product quality, reliability and conformity, as well health and environmental requirements are fulfilled.

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1 Scope

This document specifies requirements for pads for disc brakes of railway rolling stock.

The document defines requirements and generic test programs for brake pads on dynamometer. This document does not cover mandatory tests to verify stopping distances in addition to laboratory, bench test and in-service tests. In order to qualify the brake pad performance in accordance with the classification the standard provides fixed parameter figures as categories defined in paragraph classification scheme.

This document is not applicable for urban rail applications.

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 14478:2017, *Railway applications - Braking - Generic vocabulary*

EN 14535-1:2019, *Railway applications - Brake discs for railway rolling stock - Part 1: Brake discs pressed or shrunk onto the axle or drive shaft, dimensions and quality requirements*

EN 14535-2:2019, *Railway applications - Brake discs for railway rolling stock - Part 2: Brake discs mounted onto the wheel, dimensions and quality requirements*

 deleted reference 

EN 16451:2015, *Railway applications - Braking - Brake pad holder*

 EN ISO 21920-2:2022, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters (ISO 21920-2: 2021, Corrected version 2022-06)* 

 deleted reference 

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14478:2017, EN 14535-1:2019, EN 14535-2:2019 ^{A1} *deleted text* ^{A1} and the following 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 <https://www.iso.org/obp/ui>

3.1

instantaneous coefficient of friction

instantaneous value of coefficient of friction of the friction couple brake pad/brake disc at any instant during braking

3.2

static coefficient of friction

coefficient of friction achieved by the friction couple at the point where relative movement between the brake pad friction face and brake disc friction face begins

3.3

brake disc temperature

arithmetic average value of the temperature measurements on the brake disc friction faces

3.4

contact surface area

static contact surface of the brake pad available for frictional engagement with the brake disc friction face

3.5

friction material

consumable portion of the brake pad that acts on the friction face of the brake disc in order to provide the specified brake performance

3.6

brake pad

assembly of friction material and an associated fixing element acting on one friction face of a brake disc

Note 1 to entry: A brake pad can be manufactured in one piece or comprise two separate parts. Where manufactured in two separate halves, the brake pad comprises one left-hand and one right-hand half. For a brake disc four brake pad halves or two brake pads can be used.

^{A1}

3.7

continuous brake application 1

brake application which represents the Gotthard-Ramp with friction brakes only

3.8

continuous brake application 2

brake application which represents the reference case of TSI Loc&Pas to perform a continuous brake application in load condition 'maximum braking load' at speed equal to 90 % of the maximum operating speed on maximum descending gradient of 35 ‰ during 6 km with friction brakes and a train resistance (25 % of the total brake force) ^{A1}

4 Symbols and abbreviations

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

Table 1 — Symbols and abbreviations

Symbol	Designation	Unit
F_B	Nominal application force per brake disc	kN
F_b	Instantaneous application force per brake disc	kN
m	Mass to be braked per brake disc (inclusive of the rotational masses)	t
Q	Water flow rate	l/h
R_a	Refer to A1 EN ISO 21920-2 A1	μm
R_z	Refer to A1 EN ISO 21920-2 A1	μm
s_2	Stopping distance from the moment on when $F_b = 0,95 F_B$ to rest	m
v_0	Theoretical initial speed at the brake application initiation	km/h
v	Instantaneous speed	km/h
v_{max}	Maximum service speed	km/h
μ_a	Friction coefficient (brake pad): The instantaneous friction coefficient specified at every instant of the braking time	—
$\mu_m = \frac{1}{s_2} \cdot \int_0^{s_2} \mu_a \cdot d_s$	Mean friction coefficient: The mean friction coefficient μ_m integrated over the time from where 95 % of the nominal application force F_B is reached over the stopping distance s_2	—
$\mu_{m,\text{nom}}$	Nominal friction coefficient (brake pad)	—
θ_0	Mean initial temperature at the beginning of the brake application	°C
CI	Cast iron	
MU	Multiple unit (EMU/DMU)	
SBP	Standard brake pad	

5 Characteristics and test method of the brake pads

5.1 Classification of brake pads

This document defines the characteristics required for the categories A1 to G1 of brake pads, listed in Table 5. The characteristic requirements for the application in coaches used in general operation are listed in Table 7.

A1 Brake pads that have a valid UIC certification (preliminary or full) comply with EN 15328:2020 for the corresponding vehicle and energy class.

Brake pads which comply with EN 15328:2020 can retain the declaration of conformity to EN 15328 for a period of ten years after the declaration was issued. New declarations of conformity shall relate to the current released version of the standard.

NOTE The declaration of conformity can be issued by the manufacturer on the basis of the test results. An example of the declaration of conformity is given in Annex I.

As an alternative to the vehicle and energy class specific test program, a project specific test program in accordance with Annex E may be applied. **A1**

5.2 Coefficient of friction

The coefficient of friction should be independent of the wear (full thickness of the brake pad), the specific pressure, the temperature and the environmental conditions.

In wet conditions, or when there is snow, the instantaneous coefficient of friction should vary only slightly compared to the coefficient of friction under dry conditions.

These frictional characteristics shall be assessed in accordance with 5.5 to 5.6.

5.3 Environmental impact, health and safety

All raw materials used in the manufacture of the brake pads shall comply with the relevant requirements for environment, health and safety.

NOTE Relevant requirements are given in regulations of environment, health and safety, notably REACH regulations.

In addition, a safety data sheet shall be presented.

5.4 Usage requirements

The composition of the material from which the brake pads are made should be chosen so that the best compromise is obtained between:

- the frictional properties,
- the wear of the brake pads, and
- the aggressiveness against the brake disc.

5.5 Frictional requirements for brake pads

5.5.1 General

This subclause describes the requirements for brake pads used in locomotives, MUs, freight wagons and coaches. Optional test programs and requirements for coaches are defined in 5.6.

5.5.2 Priority levels of brake applications

In the test programs A1 to G1, the brake applications are prioritized, in accordance with a decreasing level of importance, as given in Table 2.

Brake applications with highest nominal application force (highest nominal deceleration) under normal conditions representing emergency brake applications are rated with priority 1. All other brake applications are rated according to their safety relevance with priorities 2 to 4. Continuous and parking brake applications are not stopping brake applications and therefore assessed according to different criteria and there is no priority level assigned with these brake applications. Bedding brake applications which are carried out prior to the main stopping brake applications are assessed separately.

Table 2 — Priority levels of brake applications for test programs

Priority level	Type of brake application
1	Dry brake applications with the highest nominal application force for each mass, normal conditions
2	Wet brake applications and hot brake applications with highest nominal application force, for each mass
3	Brake applications with highest nominal application force used for cleaning, drying, regenerating, or after continuous brake applications, for each mass
4	All other brake applications, with the exception of continuous brake applications and bedding brake applications and the examination of static coefficient of friction
—	Continuous brake applications, brake applications used for bedding-in, examination of static coefficient of friction

Normal conditions refer to brake applications under dry conditions with low initial temperature and with the brake disc and the brake pad unaffected by high thermal load or residual wetness.

Brake pads of categories A1 to G1 are characterized by their friction behaviour, expressed as the velocity-dependent nominal line.

The nominal line for the coefficient of friction is calculated for each brake pad and each test program as the linear regression line of the mean coefficients of friction (expressed in a rounding range of 0,001) versus speed of all brake applications with priority 1, extending from the lowest to the highest test speed.

5.5.3 Criteria for the nominal line

The nominal line should lie between 0,300 and 0,450.

It shall lie between 0,280 and 0,470. The difference between the maximum value and the minimum value of the nominal line shall be less or equal to 0,150.

5.5.4 Criteria for the mean coefficient of friction

Allowed deviations of coefficients of friction are expressed by means of tolerance bands centred around the nominal line.

The tolerance bands for the mean coefficients of friction in accordance with their priority level are given in Table 3.

Table 3 — Tolerance bands for the mean coefficients of friction vs. priority levels

Priority level of brake application	1	2	3	4
Tolerance band 1	±10 %	±15 %	±20 %	±25 %
Tolerance band 2	±15 %	±20 %	±25 %	±30 %

The mean coefficient of friction for each brake application shall lie within the bounds of the tolerance band 1 in accordance with its priority, while the following exceptions are tolerated.

- A total of 6 % of all brake applications (rounded to the closest integer) of priority 1 may deviate from tolerance band 1 towards the negative side.
- A total of 12 % of all brake applications (rounded to the closest integer) of priority 1 may deviate from tolerance band 1.
- A total of 5 % of all brake applications (rounded to the closest integer) of priorities 2 to 4 may deviate from tolerance band 1 towards the negative side.
- A total of 10 % of all brake applications (rounded to the closest integer) of priorities 2 to 4 may deviate from tolerance band 1.

No mean coefficient of friction shall lie outside of tolerance band 2.

5.5.5 Criteria for continuous brake applications

During continuous brake applications, after 10 s the instantaneous coefficient of friction shall stay inside the band defined by $\mu_{\min} = 0,250$ and $\mu_{\max} = 0,500$.

After 2 minutes the instantaneous coefficient of friction shall not vary more than 0,05 during any minute and the coefficient of friction shall stay inside the band defined by $\mu_{\min} = 0,250$ and $\mu_{\max} = 0,500$.

The brake pad wear during any continuous brake application, including the stop brake application thereafter, shall not exceed 1 mm. The wear in mm can be calculated from the weight differences before and after the continuous brake application.

5.5.6 Criteria for bedding brake applications

The nominal coefficient of friction of the bedded state shall be defined as the average of measured mean coefficients of friction μ_m of the last 5 braking stops carried out during the bedding section.

During the bedding-in phase, the mean coefficients of friction shall not exceed the following variations from the nominal value of the bedded state:

- ± 30 % from the 11th bedding-in brake application until 30 % of number of the bedding-in applications are finished;
- ± 15 % during the rest of the bedding-in process.

5.6 Requirements and optional test programs for brake pads for coaches

5.6.1 General

The frictional requirements for brake pads in coaches used in generic operation are described in 5.6.2 to 5.6.6. The optional test programs are defined in S1.1 and S2.1 for organic material and T1 and T2 for sintered material, and may be used instead of energy class C0 (see Annex C).

5.6.2 Tolerance ranges

The tolerance ranges for the instantaneous and mean coefficients of friction on a dry brake disc are given for the respective applications in the figures of the corresponding annexes. The instantaneous and the mean coefficients of friction measured in the test bench tests shall be documented in the appropriate tolerance diagrams. For the highest nominal application forces of the test program the mean coefficients of friction are summarized in a separate tolerance diagram and documented in tabular form. The average value of these mean coefficients of friction at a speed of 120 km/h at the highest nominal application force (excluding brake application with high initial temperatures) shall not vary more than 10 % upwards or 5 % downwards from the nominal coefficient of friction given in the tolerance diagram of the respective test program. At speeds above 120 km/h, the average values of these mean coefficients of friction shall not vary more than 10 % upwards or 10 % downwards from the nominal coefficients of friction.

5.6.3 Criteria for continuous brake applications

During continuous brake applications, after 10 seconds the instantaneous coefficient of friction shall stay inside the band defined by $\mu_{\min} = 0,250$ and $\mu_{\max} = 0,500$.

After 2 minutes the instantaneous coefficient of friction shall not vary more than 0,05 during any minute and the coefficient of friction shall stay inside the band defined by $\mu_{\min} = 0,250$ and $\mu_{\max} = 0,500$.

5.6.4 Criteria for bedding brake applications

The mean coefficient of friction of the bedded state shall be defined as the average of measured mean coefficient of friction of the last 5 braking stops carried out during the bedding section.

During the bedding-in phase, the mean coefficients of friction shall not exceed the following variations from the nominal value of the bedded state:

- $\pm 30\%$ from the 11th bedding-in brake application until 30 % of number of the bedding-in applications are finished;
- $\pm 15\%$ during the rest of the bedding-in process.

5.6.5 Coefficient of friction under high thermal load

For brake applications to a stand, which are done from a high initial temperature (approximately 140 °C, excluding brake application after continuous brake applications and for two consecutive emergency brake without cooling time), the mean coefficient of friction under otherwise similar conditions shall not vary by more than $\pm 15\%$ from the average of the mean coefficients of friction of brake applications initiated from the cold and dry condition.

5.6.6 Coefficient of friction under wet conditions

In wet conditions, with the highest nominal application force of test **A1** programs **A1** S2.1 and T2 the mean coefficient of friction shall not vary – all other things being equal – by more than $\pm 15\%$ compared with the average of mean coefficients of friction obtained during braking under dry conditions. The mean coefficients of friction of the other brake applications to a stand of this test program shall not under-run the absolute value of $\mu_m = 0,250$ under otherwise similar conditions.

5.7 Geometrical features of the brake pads

5.7.1 Brake pad shape

The SBP shall be designed in accordance with Annex F.

5.7.2 Brake pad wear

The design of the brake pads shall enable them to wear uniformly to a friction material thickness of 5 mm or defined by design specification.

5.7.3 Brake pad fixing

The brake pads should be affixed to the vehicle by pushing them into a dovetail. If the brake pad is used with a brake pad holder in accordance with EN 16451:2015 the dove tail shall be designed in accordance with Annex G.

5.8 Mechanical, physical and chemical characteristics

The mechanical, physical and chemical characteristics shall be homogeneous across the entire active thickness.

The brake pads shall not deform under the effect of heat or humidity so that they can no longer be fitted or removed.

A material data sheet, on which sufficient mechanical and physical characteristics of the friction material are given, shall be presented so that by quality testing or subsequent inspections it is possible to check that these characteristics have not changed and the brake pad actually conforms to the approved brake pad material.

The organic and sintered brake pads shall be tested in accordance with Table 4. For other materials the mechanical and physical test characteristic shall be agreed before the test.

The results serve as a database for the material data sheet, which shall then serve as a reference demonstrating that the brake pads subsequently manufactured during series production correspond to the brake pads used. Tests marked "A" shall be conducted with a specimen from one of the batches used for the assessment in conformity to this document.

Tests marked "B" shall be conducted with test products from each of the batches used for the assessment in conformity to this document. Friction parameters shall be derived from at least three batches.

Table 4 — Reference tests for quality assurance

	Organic brake pads	Sintered brake pads
Chemical composition ^a	A	A
Macrostructure	—	A
Hardness or compressibility ^b	B	B
Coefficient of friction (small scale bench tests for brake pads)	B	B
Density	B	B
Resistance to high temperatures ^c	—	A
^a Results for chemical analysis are confidential. They are not included in the test report. They have to be retained for future comparison. ^b Shall be defined before assessment. ^c For resistance to high temperatures tests, unless otherwise specified, the maintaining of the brake pad stud at temperatures of $(710 \pm 5) ^\circ\text{C}$ for 1,5 h shall not cause any variation in thickness $> 3 \%$ after cooling down in comparison to the width registered before the start of the test.		

At least the following information shall be provided with the data sheet of a brake pad:

- energy class;
- nominal line for the friction coefficient;
- range of specific pressure;
- maximum sliding speed at the brake radius;
- maximum temperature sustained;
- maximum temperature momentarily sustained;
- density.

The test results shall be attached to the test report. The test method and the tolerance band for each property shall be defined in accordance with the product itself and the production process.

Hardness/compressibility, coefficient of friction (small-scale bench tests for brake pad material) and density shall be tested with:

- a) test samples taken from an area near the contact surface,
- b) test samples taken from an area near the wear limit.

Comparison of the results from A and B shall show that the material is homogeneous and retains its properties across the entire active thickness.

5.9 Thermal and mechanical requirements

The shape, number and arrangement of the rubbing parts on the carrier plate shall be designed to achieve a most uniform temperature distribution in the brake disc.

During friction bench testing the following shall not occur:

- flames;
- blow-outs or exfoliation over an area of more than 10 % of the brake pad surface;
- any damage jeopardizing the mechanical strength of the brake pad, leading to significant material deposits on the brake disc or creating unusual levels of wear.

5.10 In-service assessment

The in-service assessment is not requested by this document for the generic classification.

If an in-service assessment is requested for a specific application it should be performed in conformity with Annex H.

5.11 Marking of brake pads

On the back of each part of a brake pad, there shall be the following marks:

- name or abbreviation of the manufacturer;
- year of manufacture;
- week and/or number of batch;
- brake pad-abbreviation (material).

The marks shall be so applied, that each brake pad can still be identified even after it has worn to its scrapping thickness.

5.12 Dynamometer tests

The tests shall be performed by a competent laboratory.

NOTE 1 As an example, a test institute in accordance with EN ISO/IEC 17025.

Generic conditions for the execution of test programs shall be in accordance with Annex A.

Brake pads of the full scale size shall be used. Each test program shall be carried out with new brake pads.

The test report shall conform to the minimum requirements of Annex D.

The dynamometer used for conducting the tests provided in the Annexes should be suitable for carrying out these tests in the correct manner.

NOTE 2 Existing document that defines the requirements of dynamometers for Railway Friction Material testing at the time of writing this document include [A1](#) UIC/IRS 50548 [A1](#) and can be used as reference document.

5.13 Conditions for classification tests

5.13.1 Classification scheme for locomotives, MUs, high-speed trains, freight wagon and coaches

The classification of the brake pads is defined in Table 5.

Table 5 — Classification of brake pads for locomotives, MUs, high-speed trains, freight wagons and coaches

Class	Max. energy MJ	Max. power kW	Max. speed km/h	Braked mass t	Approximate deceleration rate m/s ²	See Annex B
A1	6,3	338	120	11,25	0,9	B.1
B1 ^a	7,9	427	160	8	1,2	B.2
B2 ^b	9,9	533	160	10	1,2	B.3
C0	10,3	447	200	6,7	1,2	B.4
C1 ^a	12,3	533	200	8	1,2	B.2
C2 ^b	15,4	667	200	10	1,2	B.3
C3	18,5	800	200	12	1,2	B.5
D1	15,7	361	250	6,5	0,8	B.6
D2	25,3	583	250	10 ^{A1}	0,8	B.7
E1	27,8	533	300	8	0,8	B.8
F1	23,6	389	350	5	0,8	B.9
F2 ^c	28,4	467	350	6	0,8	B.10
F3	33,1	544	350	7	0,8	B.11
G1 ^c	37	533	400	6	0,8	B.10
^a Classification in accordance with class C1 includes classification in accordance with class B1. ^b Classification in accordance with class C2 includes classification in accordance with class B2. ^c Classification in accordance with class G1 includes classification in accordance with class F2.						

An overview of types of vehicles and energy classes is given in Table 6.

Table 6 — Type of vehicles and energy classes

Class	Vehicle type
A1	Freight wagons in SS traffic with axle mounted brake disc
B1	MUs with maximum speed of 160 km/h with wheel mounted brake discs
B2	MUs with maximum speed of 160 km/h with wheel mounted brake discs
C0	Passenger coaches with maximum speed of 200 km/h with axle mounted brake discs
C1	MUs with maximum speed of 200 km/h with wheel mounted brake discs
C2	MUs with maximum speed of 200 km/h with wheel mounted brake discs
C3	Locomotives with maximum speed of 200 km/h with wheel mounted brake discs
D1	MUs with maximum speed of 250 km/h with axle mounted brake discs
D2	MUs with maximum speed of 250 km/h with wheel mounted brake discs
E1	high speed trains with maximum speed of 300 km/h with wheel mounted brake discs
F1	high speed trains with maximum speed of 350 km/h with axle mounted brake discs
F2	high speed trains with maximum speed of 350 km/h with axle mounted brake discs
F3	high speed trains with maximum speed of 350 km/h with wheel mounted brake discs
G1	high speed trains with maximum speed of 400 km/h with axle mounted brake discs

Classification tests for brake pads shall be carried out with the test program corresponding to the class to which it is sought.

5.13.2 Optional classification scheme for coaches

The classification of the brake pads for use in coaches is given in Table 7 and programs are defined in Annex C.

Table 7 — Optional classification of brake pads for coaches

Type (class)	Max. energy MJ	Max. power kW	Max. speed km/h	Braked mass t	Deceleration rate m/s ²	Test program(s)
S1.1, S2.1	10,3	447	200	6,7	1,2	programs S1.1 and S2.1
T1, T2	11,9	513	200	7,7	1,2	programs T1 and T2

5.13.3 Validity of assessment

The assessment shall not be longer valid if one the following modifications is made:

- major changes in the manufacturing methods,
- change of materials used for the brake pads,
- major changes in the fixing of the friction elements, or
- changes in the contact surface area that exceed ± 20 %.

5.13.4 Scope of classification

The scope of classification is limited to the class for which tests were conducted.

5.14 Interchangeability of brake pads

A1 The ability to obtain interchangeability of brake pads for the application in the same train can be evaluated via dynamometer testing.

NOTE Additional vehicle testing can be requested.

The tests shall be conducted at the same dynamometer either with one of the predefined test programs contained within this standard or with a test program adapted from the appropriate generic test program (Annex E) to the parameters of the train at hand. The brake disc to be used for the tests shall be of the same type that is used on the train for which brake pad interchangeability is sought.

Both brake pads shall be compliant with this standard on the basis of testing carried out defined above.

For existing fleets, one of the two brake pads shall already be used in the train and in the evaluation of the train's brake performance in the homologation process.

The difference in the values of the mean coefficients of friction of both brake pads under dry conditions at train speeds critical for brake performance evaluation shall be compliant with the criteria defined in a technical specification (e.g. do not exceed 10 % upwards or 5 % downwards of the reference value of the coefficient of friction).

At other speeds, the brake performance of both brake pads shall be greater or equal to the brake performance evaluated at the critical speed. **A1**

Annex A

(normative)

Generic conditions for the execution of test programs

A.1 General

Unless noted otherwise in the clauses devoted to the individual test programs, the following generic conditions apply to all test programs in this document.

In test programs when only one speed is indicated it is the initial speed of stopping braking and when two speeds are indicated it is slowing braking. The first speed is the initial speed and the second speed is the final speed.

A.2 Response time

Response time t_b or $t_b(1) = 4 \text{ s} \pm 0,2 \text{ s}$.

Response time $t_b(2)$, $t_b(n) = 1 \text{ s} \pm 0,15 \text{ s}$ (for brake applications with 2 or more stages of brake force).

A.3 Weighing

The brake pads shall be weighed before and after bedding-in. Further weighing points are indicated in the individual test programs.

A.4 Interruption of test sequence

The brake applications shall be performed in the correct chronological order. During the test sequence, an interruption is allowed at the end of each block of dry brake applications. To continue the test, it is necessary to repeat the last five applications from the block before. An interruption directly after a wet brake application is not allowed.

If a second set of brake pads is necessary to finalize a test program, this set shall be previously bedded-in in accordance with the requirements of the test program. The use of the second set of brake pads shall be indicated in the test report. To continue the test, it is necessary to repeat the last five applications from the block before. An interruption directly after a wet brake application is not allowed.

A.5 Temperatures

Temperatures shall be measured in accordance with A.9.

After each brake application the brake disc shall cool down to the shown starting temperature of the next brake application.

A.6 Brake applications under wet conditions

For some common brake disc sizes, the water flow rate Q during wet tests are given in the Table A.1.

Table A.1

Brake disc diameter mm	Water flow rate per brake disc (both faces) l/h
750	30,5
680	27,0
640	25,0
610	23,5
600	21,5
590	21,0

For brake disc sizes not represented in the table, the flow rate to be applied per brake disc (both faces) can be calculated with the following formula:

$$Q = Q_S \cdot A_D$$

where

A_D is the total area of wetted friction ring, being calculated as:

$$A_D = 2 \times \pi \times \left(R_0^2 - (R_0 - \Delta R)^2 \right);$$

Q_S is the specific water flow rate of 6 cm³ per cm² per hour;

R_0 is the outer radius of the brake disc, expressed in cm.

For brake discs with outer diameter greater than 600 mm, ΔR is 130 mm, while for brake discs with diameter smaller or equal to 600 mm, ΔR is 118 mm.

For the practical application, Q can be rounded to the nearest half litre per hour.

During wet brake application sequences, the water is applied continuously, also during the cooling phase of the brake disc.

After a sequence of dry brake applications, the spraying before the first wet brake application shall only begin when the brake disc temperature has reached 80 °C.

A.7 Conditioning of brake discs

A.7.1 General

Brake discs shall be conditioned before the certification program for brake pads is run. For conditioning, the same brake pad material shall be used as for the certification tests. However, the certification tests shall begin with a set of new brake pads.

Depending on the test program, a program shall be carried out to condition the brake disc.

The situation before carrying out a certification program for brake pads can be different as the four possibilities below show.

- The brake disc is new: the brake disc shall be conditioned as specified in A.7.2.
- The brake disc has grooves or small cracks after the previous program has been carried out.

The sides of the brake disc shall be machined flat as follows:

- 1) all cracks shall be removed, however one or two cracks with a length < 25 mm are tolerated in each side of the brake disc;
- 2) the following surface condition – measured with a roughness measuring instrument shall be produced: $R_a < 1,5 \mu\text{m}$ or $R_z < 7 \mu\text{m}$.

Then the conditioning is done as specified in A.7.2.

- c) Although the brake disc has no grooves, but is worn, and the friction surfaces show traces of deposits of the friction material.

Then the sides of the brake disc shall be cleaned with the previously used brake pad, with a suitable number of stopping brake applications under dry conditions until the deposits of the friction material are removed. Preferably, the bedding stops of the program shall be performed. Alternatively, it is permitted to perform stopping brake applications under dry conditions from the test program with speeds below the maximum speed.

- d) The brake disc has already been used, but has no cracks and no traces of frictional material deposits.

It is thus already conditioned and so the certification program can begin under the conditions of the test program.

A.7.2 Conditioning program

The conditioning for preparation of the brake disc consists of at least 20 brake applications of the bedding-in sequence defined in the program used for the approval tests. The conditioning shall be continued in sequences of 10 brake applications until at least $\Delta R_z < 2 \mu\text{m}$ ($\Delta R_a < 0,4 \mu\text{m}$) is obtained in two consecutive test sequences.

A.7.3 Roughness measurement

The roughness depth R_z (in accordance with  EN ISO 21920-2:2022 ) of the brake disc shall be measured at three distinct positions in the centre of the friction ring along the brake radius over a length of 4,8 mm.

A.8 Bedding-in of brake pads

The bedding-in of the brake pads is done with brake parameters as stated in the corresponding test program. It shall be carried out until

- a) 85 % of the contact area is bedded-in and
- b) incoming peaks are completely in contact with the brake disc surface.

The parameters of braking applications during bedding (speeds, times, application forces, masses, braking distances, mean coefficients of friction and temperatures) shall be noted in the report.

A.9 Methods of temperature measurements

A1 The brake ring shall be equipped with six temperature sensors positioned 1 mm below the friction surface, three on each face. For each face one sensor is positioned on the middle radius of the friction face of brake ring and the other two are positioned on the middle radius ± 40 mm, circumferentially positioned at an angle of 120° to each other.

This shall be applied except when the brake disc geometry does not allow it. In this case sliding thermocouples may be used. **A1**

A.10 Mean friction radius

The mean friction radius for any brake disc is calculated as follows:

$$r = \frac{2}{3} \cdot \frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}$$

where

r is the mean friction radius;

r_i is the inner radius;

r_0 is the outer radius of the circumferential contact area between brake disc and brake pad.

The method used to determine r_i and r_0 on the dynamometer shall be documented in the test report.

A.11 Rotation and ventilation conditions

Conditions of test programs for rotation and ventilation are given in Table A.2.

Table A.2

	Test bench speed km/h		Speed of the cooling air km/h	
	dry	wet	dry	wet
During brake application	$v < 200$ $v \geq 200$	— v	$v/2$ 100	10 10
Between brake applications	100	50	80	10
Standstill (between consecutive brake applications)	0	—	10	—

Annex B (normative)

Test programs for classes A1 to G1

B.1 Test program: brake pads of class A1

For application with masses < 4,7 t per axle (tare) and > 22,5 t per axle (laden) a generic program with masses, power of drag braking and other parameters adjusted shall be used.

Parameters of the test program for the brake pads of class A1 are given in Table B.1.

Table B.1 — Program for class A1 – freight wagons in SS traffic with max. speed 120 km/h, mass per axle $\geq 4,7$ t (tare) and $\leq 22,5$ t (laden), and deceleration rate $0,88 \text{ m/s}^2$

Brake pads					Sintered/organic Brake pad dimensions are not specified									
Brake disc					Axle mounted brake disc, 590 mm outer diameter, width ≥ 140 mm. A1 6,3 MJ max energy A1									
Wheel diameter					890 mm									
Priority	No. brake				Speed v ₀ km/h	F _B kN	Initial temp. θ ₀ °C	Braked mass per brake disc t	Comments					
—	1.1–1.X				120	31	20–100	11,25	X stop brake applications, until conditions of A.8 are met W.					
4	1	13	25	50	8,5	50–60	2,35	Dry brake applications to establish coefficient of friction - minimal mass						
4	2	14	26	80										
4	3	15	27	100										
4	4	16	28	120										
4	5	17	29	50	4,5				50–60	2,35	Dry brake applications to establish coefficient of friction - minimal mass			
4	6	18	30	80										
4	7	19	31	100										
4	8	20	32	120										
1	9	21	33	50	12,5							50–60	2,35	Dry brake applications to establish coefficient of friction - minimal mass
1	10	22	34	80										
1	11	23	35	100										
1	12	24	36	120										

Brake pads				Sintered/organic Brake pad dimensions are not specified										
Brake disc				Axle mounted brake disc, 590 mm outer diameter, width ≥ 140 mm. Ⓐ 6,3 MJ max energy Ⓐ										
Wheel diameter				890 mm										
Priority	No. brake			Speed v ₀ km/h	F _B kN	Initial temp. θ ₀ °C	Braked mass per brake disc t	Comments						
4	37	45	53	50	8,5	20–30	2,35	Wet brake applications – minimal mass						
4	38	46	54	80										
4	39	47	55	100										
4	40	48	56	120										
2	41	49	57	50	12,5				20–30	2,35	Wet brake applications – minimal mass			
2	42	50	58	80										
2	43	51	59	100										
2	44	52	60	120										
4	61	—	70	100	31	50–60	11,25	Dry brake applications to dry brake pad						
4	71	83	95	50	31	50–60	11,25	Dry brake applications to establish coefficient of friction – maximum mass						
4	72	84	96	80										
4	73	85	97	100										
4	74	86	98	120										
4	75	87	99	50	16				50–60	11,25	Dry brake applications to establish coefficient of friction – maximum mass			
4	76	88	100	80										
4	77	89	101	100										
4	78	90	102	120										
1	79	91	103	50	46							50–60	11,25	Dry brake applications to establish coefficient of friction – maximum mass
1	80	92	104	80										
1	81	93	105	100										
1	82	94	106	120										
2	107			100	46	150 150 220	11,25	Brake applications with high initial temperature						
2	108			120										
2	109			80										