UIC CODE 541-3

6th edition, November 2006

Translation

OR

Brakes - Disc brakes and their application - General conditions for the approval of brake pads

Freins - Freins à disques et leur utilisation - Conditions générales pour l'admission de garnitures de frein
Bremse - Scheibenbremse und ihre Anwendung - Allgemeine Bedingungen für die Zulassung von Bremsbelägen

UNION INTERNATIONALE DES CHEMINS DE FER
INTERNATIONALER EISENBAHNVERBAND
INTERNATIONAL UNION OF RAILWAYS

Leaflet to be classified in Volume:

V - Rolling Stock

Application:

With effect from 1 November 2006
All members of the International Union of Railways

Record of updates

1st edition, January 1977	First issue, under the title: "Brakes - Brake linings for vehicles equipped with disc brakes", and 1 Amendment
3rd edition, July 1985	and 8 Amendments
4th edition, July 1993	under the title: "Brakes - Disc brakes and disc brake pads - General conditions governing bench tests", and 5 Amendments
5th edition, November 2004	Overhaul of leaflet, retyped in FrameMaker
6th edition, November 2006	Publication of the Appendix I on the UIC website.

The person responsible for this leaflet is named in the UIC Code

Contents

Summary **1**

1 - Disc brakes **2**

1.1 - Application of disc brakes 2
1.2 - Use of brake pads 2
1.3 - Fitness for service 2
1.4 - Indicating equipment 2
1.5 - Braked weights 3
1.6 - Vehicle lettering 3

2 - Brake pads for vehicles equipped with disc brakes **4**

2.1 - Characteristics of the brake pads 4
2.1.1 - General 4
2.1.2 - Frictional requirements 5
2.1.3 - Geometrical features of the brake pads 6
2.1.4 - Mechanical, physical and chemical characteristics 7
2.1.5 - Marking of approved brake pads 7
2.2 - Approval of brake pads 8
2.2.1 - Approval procedure 8
2.2.2 - Conditions for approval tests on the test bench 8
2.3 - Validity of approval 10

Appendix A - Examples of drawings of brake pads **11**

A.1 - Brake pad half 200 cm^2 made of organic materials 11
A.2 - Brake pad half 175 cm^2 made of organic materials 12
A.3 - Brake pad halves made of sintered material, surface area 200 cm^2 13
A.4 - Brake pad holder for brake pads (175 cm^2 and 200 cm^2) 14
A.5 - Brake pad with a surface area of 140 cm^2 15

Appendix B - Requirements for organic and sintered brake pads (v_{max} = 300 km/h) **16**

B.1 - Test programme No. 1 (v_{max} = 300 km/h) 17
B.2 - Instantaneous coefficient of friction 19
B.3 - Average coefficient of friction 19

Appendix C - Requirements for composite brake pads for use on RIC vehicles with v_{max} = 140 and 200 km/h 20

C.1 - Test programme No. 2A (v_{max} = 140 km/h) 21

C.2 - Test programme No. 2B (v_{max} = 200 km/h) 23

C.3 - Test programme No. 2C (v_{max} = 200 km/h, multiple unit trains with wheel brake discs) 26

C.4 - Test programme No. 3A (wet tests) 27

C.5 - Test programme No. 3B (severe winter conditions) 29

C.6 - Instantaneous coefficient of friction 31

C.7 - Average coefficient of friction 31

Appendix D - Requirements for brake pads for freight wagons 32

Appendix E - Requirements for sintered brake pads, v_{max} = 300 km/h, two stage pressure 33

E.1 - Test programme No. 5 34

E.2 - Instantaneous coefficient of friction 37

E.3 - Average coefficient of friction 37

Appendix F - Requirements for sintered brake pads for passenger coaches (v_{max} = 200 km/h) 38

F.1 - Test programme No. 6A 39

F.2 - Test programme No. 6B (wet tests) 42

F.3 - Test programme No. 6C (v_{max} = 200 km/h, multiple unit trains with wheel brake discs) 44

Appendix G - Requirements for locomotive brake pads (v_{max} = 230 km/h) 45

Appendix H - Requirements for friction test benches 46

H.1 - Test methods and measurements to be carried out 46

H.2 - Test bench (wetting device) 50

H.3 - Measuring point for brake pad force Fb/2 51

H.4 - Axle brake disc with one piece rubbing ring 52

H.5 - Conditions for the international approval of friction test benches 53

H.6 - Internationally approved friction test benches 55

Appendix I - Brake pads approved for international traffic 56

Appendix J - Terms used 57

Bibliography 61

Summary

This Leaflet contains the general conditions for disc brakes and their indicating equipment. The properties required for brake pads are specified as well as their frictional and geometrical requirements and the mechanical, physical and chemical features of both organic brake pads and sintered brake pads for different categories of vehicles.

The approval procedure for brake pads including the test programmes to be used for each type is described. The instantaneous and the average coefficients of friction to be achieved are shown in diagrammatic form. The validity of the approval expires after a certain time.

The internationally approved brake pads are listed by different applications in tables and the same is true for the internationally approved brake test benches.

The Leaflet is completed by a glossary of terms, the test methods and measurements to be made.

1 - Disc brakes

o 1.1 - Application of disc brakes

Vehicles fitted with disc brakes (as well as those combined with additional block brakes) may be used in international traffic.

o 1.2 - Use of brake pads

The brake pads to be used shall be approved as specified in point 2.2 - page 8. The Table of point 2.2.2.1 - page 8 gives their fields of application, classified according to vehicle category. Category 4, Passenger coaches, is correct for the brake pads approved up to the 4th issue of the Leaflet. Pads of the types 4.1 to 4.3 meet the requirements for RIC vehicles. The pad type 4.4 is reserved for those RUs which have to operate under difficult winter conditions. If these pads are to be used on vehicles that cross frontiers this needs to be approved bilaterally depending on the application. These pads are specially marked as specified in point 2.1.5 - page 7. The other fields of application apply for the use in international traffic and produce approval conditions for the TSI-requirements as well.

o 1.3 - Fitness for service

In order to check that the brakes are operating properly, a "brake on/brake off" indicator must be fitted in a clearly visible position on each side of the vehicle. The "brake on" state must be indicated by a red indicator and the "brake off" state by a green indicator.

On vehicles fitted with several distributors, there must be a separate indicator for each distributor.

The area of a display field shall be about 2 400 mm^2. In the centre of the red display field, there is a dark field 15 mm in diameter or a continuous black line 10 mm wide.

1.4 - Indicating equipment

O **1.4.1 -** When pressure is applied to the brakes, the "brake on/brake off" indicators must make it possible to check with precision whether the compressed-air brakes of the vehicle are on or off and whether the hand brakes are off. When the indicators show a green field (brake off), this must ensure that both brakes - compressed-air and handbrake - really are off. The indicators showing the position of the handbrake must be marked with the "handbrake" symbol .

NB : The "handbrake" symbol  is not obligatory for existing vehicles if the indicator for the handbrake is adjacent to the handbraked bogie.

R **1.4.2 -** It is recommended that the handbrakes on wagons be checked by means of indicators.

R **1.4.3 -** The indicator units may have an extra device consisting of a diagonal black cross on a white background to indicate that the indicator unit is temporarily non-operational.

R **1.4.4 -** It is recommended that the indicator unit "brake applied - brake released" should be located in the vicinity of the operating equipment for the brake gear.

o 1.5 - Braked weights

The braked weights of vehicles fitted with disc brakes shall be determined in accordance with the method defined in *UIC Leaflet 544-1* (see Bibliography - page 61).

o 1.6 - Vehicle lettering

Vehicles with disc brakes (and those fitted with the additional block brakes) shall be identified with the mark Ⓓ in accordance with *UIC Leaflet 545, Appendix G* (see Bibliography - page 61).

This mark shall be applied behind the abbreviated brake designation.

2 - Brake pads for vehicles equipped with disc brakes

2.1 - Characteristics of the brake pads

2.1.1 - General

O **2.1.1.1 -** This specification defines the characteristics required of brake pads made of organic and sintered materials for the categories of vehicles listed in the table in point 2.2.2.1 - page 8.

The tolerance ranges for the instantaneous coefficient of friction (μ_a) and the average coefficient of friction (μ_m) are given for the corresponding test programme - see the table under point 2.2.2.1.

The design of the vehicle brake equipment shall be based on the nominal value of the μ_m curve (in which the appropriate coefficient of friction diagrams are shown).

O **2.1.1.2 -** Brake pads of organic and sintered materials work on the brake discs made of cast steel, forged steel or cast iron attached to the wheels or axles.

Small brake pads with 140 cm^2 rubbing surface may act directly on the side surfaces of the wheels.

O **2.1.1.3 -** The composition of the material and the method of manufacture of the brake pads in current production must agree with that of the pad that was approved.

O **2.1.1.4 -** The use of asbestos is forbidden.

R **2.1.1.5 -** The use of the metals lead or zinc, even in the form of compounds, is not recommended; this also applies to any other materials which, when the pads are in use, may produce dust, particles or gas likely to be a health risk or unpleasant for passengers.

O **2.1.1.6 -** The composition of the material from which the brake pads are made shall be so chosen, that the best compromise is obtained between:

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

O **2.1.1.7 -** The characteristics laid down in this leaflet must be complied with over the full thickness of the brake pads.

2.1.2 - Frictional requirements

2.1.2.1 - As far as possible the coefficient of friction shall be independent of the extent to which the pads are bedded-in, the specific pressure, the temperature and the weather effects. The frictional requirements for various applications of the brake pads are described in the test programmes No. 1 to 6. The permissible coefficients of friction for universal use in RIC traffic are described in Appendix C (points C.1 - page 21 to C.6 - page 31) and for special applications in Appendices B - page 16 and D - page 32 to G - page 45.

O **2.1.2.2 -** The tolerance ranges for the instantaneous and average coefficients of friction (for definitions, see Appendix J - page 57) on a dry disc are given for the respective applications in the diagrams of the corresponding Appendices and in the table of point 2.2.2.1 - page 8. The instantaneous and the average coefficients of friction measured in the test bed tests shall be documented in the appropriate tolerance diagrams. For the highest contact pressures of the test programme the average coefficients of friction are summarised in a separate tolerance diagram and documented in tabular form. These average coefficients of friction at the highest contact force shall, if possible, not vary either upwards or downwards from the nominal coefficient of friction given in the tolerance diagram of the respective test programme in the area of the initial speed at which the brake application was made ≥ 100 km/h.

During the bedding-in period, these coefficients of friction may not vary by more than ± 15% from the values obtained under the same conditions when the bedding-in process is complete.

O **2.1.2.3 -** In wet conditions or when there is snow, the coefficient of friction at any given moment should vary only slightly compared to the coefficient of friction under dry conditions. The capacity for the elimination of ice should be as high as possible. The coefficient of friction must immediately return to its value under dry conditions once these disruptive influences have ceased.

In wet conditions, with the highest contact pressure of test programme 3A (Appendix C, point C.4 - page 27, simulation of wet conditions) the average coefficient of friction must not vary - all other things being equal - by more than ± 15% compared with the average coefficient of friction obtained during braking under dry conditions. The average coefficients of friction of the other brake applications to a stand of this test programme may not exceed the absolute value of μ_m = 0,25 under otherwise similar conditions.

The average coefficients of friction of wet brake applications with the highest pressure in the test programme 3B (simulation of severe winter conditions) may not be less than the value μ_m = 0,15 under otherwise similar conditions. For the remaining brake applications the absolute value shall not be less than μ_m = 0,1.

O **2.1.2.4 -**

1. For brake applications to a stand, which are done from a high initial temperature (≥ 140°C), the average coefficient of friction under otherwise similar conditions may not vary by more than ± 15% from the average of brake applications initiated from the cold (≤ 60°C) and dry condition.

2. For continuous braking (when running down inclines) with a maximum power of 43 kW per brake disc, the instantaneous coefficient of friction shall meet the following conditions:

   - after 2 minutes braking: μ_{min} = 0,25 and μ_{max} = 0,40
   - during the whole of the braking period: μ_{min} = 0,25, μ_{max} = 0,50 and $\Delta\mu_a \leq 0,15$

Moreover the coefficient of friction must not experience any sudden variations and so disturb the operation and the controllability of the brake. During a minute, the instantaneous coefficient of friction shall not increase or drop by more than 0,05 ($|\Delta\mu_a| \leq 0,05$).

2.1.3 - Geometrical features of the brake pads

2.1.3.1 - Organic brake pads (two part or monobloc) are used with thicknesses of 24 or 35 mm; the dimensions are specified with the tolerances in Appendix A - page 11.

Appendix A, point A.1 - page 11 shows a brake pad half with a rubbing area of 200 cm^2. This pad can be used on internally ventilated axle brake discs from 610 mm up to 640 mm external diameter.

Brake pads with a rubbing area of 175 cm^2 as shown in Appendix A, point A.2 - page 12 can be used in internally ventilated axle brake discs from 510 mm up to 610 mm external diameter.

Brake pads with a rubbing surface of 140 cm^2 have a geometrical shape as shown in Appendix A, point A.5 - page 15. These pads are arranged horizontally over the axle and can be used for brake ring surfaces from 330 mm to 440 mm external diameter.

2.1.3.2 - The maximum pad thickness of sintered brake pads shall be 35 mm. The shape, number and arrangement of the rubbing parts on the carrier plate shall be designed to achieve a uniform temperature distribution in the brake disc. Its shape shall:

- either correspond to the requirements of the RUs (e.g. Appendix A, point A.3 - page 13),
- or appear like that for organic pads.

2.1.3.3 - The design of the brake pads must enable them to wear uniformly to a frictional material thickness of 5 mm, without the reinforcement, if fitted, coming into contact with the brake disc.

2.1.3.4 - The brake pads shall be affixed to the vehicle by pushing them into a dovetail shaped cut out in the brake pad holder and locking them in.

The design of the dovetail section is shown in Appendix A, points A.1 - A.4 - page 14.

The pads with 140 cm^2 rubbing surface have a different fixing system.

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

2.1.3.6 - In no case may the arrangement of the rubbing parts cause the pad to overlap the outer or inner diameter of the rubbing ring when the vehicle has average spring deflection.

2.1.4 - Mechanical, physical and chemical characteristics

2.1.4.1 - Manufacturer's data sheet

The manufacturer of sintered brake pads or organic brake pads shall submit a data sheet, on which sufficient mechanical, physical and chemical characteristics are given, 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.

2.1.4.2 - Mechanical requirements

1. When delivered and up to the assembly on the vehicle (after holding in stores) the frictional material must be sufficiently homogeneous that its assembly, as well as its use up to the wear limit, is neither affected by defects (craters, bubbles, cracks, etc.), which could cause brittleness, nor by any deformation or cracking. Consequently a loss of rubbing elements or parts of the rubbing material on the track should be prevented.

2. The method of bonding the frictional material to the carrier plate is left to the manufacturer. This shall be done in such a way that the operating loads that occur can be withstood.

2.1.4.3 - Thermal requirements

1. The frictional material shall not cause any thermal damage on the brake disc (burn marks and thermally initiated cracks, which can lead to fracture of the disc). Also the adjacent rubbing surface shall not be attacked nor should it tend to form metallic inclusions.

2. The brake pad shall withstand the thermal loading within the limits of the approval programme without burning, melting, or forming large deposits on the brake disc or wearing unusually quickly.

   The frictional material shall be able to withstand without worsening of its properties the following temperatures, measured on the rubbing surfaces of the brake discs:

   - for organic brake pads: 400°C,
   - for sintered brake pads: 550°C.

2.1.5 - Marking of approved brake pads

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

- name or abbreviation of the manufacturer,

- date of manufacture (week and year),

- pad-abbreviation (material),

- type designation of the pad: "UIC-xx" (e.g. "UIC-42" for a type 4.2 pad; the type specified in the table of point 2.2.2.1 - page 8).

These marks shall preferably be stamped, engraved or punched and shall be so applied, that each pad can still be identified even after it has worn to its scrapping size.

2.2 - Approval of brake pads

2.2.1 - Approval procedure

O **2.2.1.1 -** Each RU which puts forward an application for approval for the use of a new brake pad in international traffic, shall establish by carrying out tests on the test bench in accordance with the method given in Appendix H - page 46 (with brake discs of diameters 590, 610 or 640 mm and suitable pads), whether its features correspond to those given in the approval conditions defined in points 2.1 - page 4 and 2.2.2.

O **2.2.1.2 -** The RU, which submits a brake pad shall check that it is satisfactory and, among other things, that it is not too aggressive on the brake discs by tests in service. This investigation shall be carried out on several trains under different weather conditions without interruption for at least a year. These service tests must produce evidence that the brake pad corresponds to the application conditions given in the approval application.

A detail report shall be prepared on this service testing.

R **2.2.1.3 -** If the RU that makes the application does not have the necessary equipment, the tests can be carried out by another RU.

O **2.2.1.4 -** The application for approval shall be submitted with the various test reports (25 copies in two of the three UIC languages) to the UIC Study Group 5 "Braking and running gear", who shall decide whether to approve it. The SG5 retains the right to withdraw an approval if there are justifiable reasons by granting a transition period.

For a list of the approved brake pads see Appendix I - page 56.

O 2.2.2 - Conditions for approval tests on the test bench

2.2.2.1 - The tests should preferably be carried out with a brake disc as per Appendix H (with the exception of the test programmes 2C, 6C, 7A, 7B as well as 4C and 4D) with the programmes given in the following Table. The RU that applied for the approval shall specify, bearing in mind the proposed application of the pad, the vehicle categories, and the type. The Table then gives the test programme to be used and tolerance ranges for the permitted coefficient of friction.

The use of programme 3B for special and extreme winter conditions is not obligatory for the general approval of pads for use in international traffic. It is carried out in addition when such pads are to be tested and approved:

Vehicle category	Type	v_{max} [km/h]	Brake pad material	Test programme to be carried out	Test programme (see points)	Tolerances μ_a (see points)	Tolerances μ_m (see points)
Category 1 **High-speed trains**	**1.1**	300 (max. 13,8 MJ)	organic or sintered	1 and 3A	B.1 C.4	B.2 C.6	B.3 C.7
	1.2	300 (max. 17,8 MJ)	sintered	5 and 3A	E.1 C.4	E.2 C.6	E.3 C.7
Category 2 **Multiple unit trains with wheel brake discs**	**2.1**	200	organic	2C and 3A	C.3 C.4	C.6 C.6	C.7 C.7
	2.2	200	sintered	6C and 3A	F.3 C.4	C.6 C.6	C.7 C.7
Category 3 **Locomotives**	**3.1**	230	organic or sintered	7A and 3B	G.1 G.2	G.3 reserved	G.4 reserved
Category 4 **Passenger coaches**	**4.1**	140	organic	2A1 or 2A2 and 3A	C.1 C.4	C.6 C.6	C.7 C.7
	4.2	200	organic	2B1 or 2B2 and 3A	C.2 C.4	C.6 C.6	C.7 C.7
	4.3	200	sintered	6A and 3B	F.1 F.2	C.6 C.6	C.7 C.7
Extreme-winter conditions	**4.4**	200	organic	2B1 or 2B2 and 3A and 3B	C.2 C.4 C.5	C.6 C.6 -	C.7 C.7 0,15/0,10[a]
Category 5 **Wagons**	**5.1**	160	organic or sintered	4A and 4B	D.1 D.2	D.5 D.5	D.6 D.6
Low floor wagons (RoLa)	**5.2**	120	organic or sintered	4C and 4B	reserved	reserved	reserved

a. See point 2.1.2.3.

In these tests brake applications shall be made to a stand from various starting speeds with various applied forces and temperatures in dry and wet conditions, as well as incline brake applications. The wear shall be determined by weighing.

The spraying equipment shown in Appendix H, point H.2 - page 50 shall be used to carry out the wet test

2.2.2.2 - Only brake pads of the original size may be used. Each test programme shall be carried out with new pads.

2.2.2.3 - The test benches used for the approval tests and the test runs shall be approved as specified in the conditions of Appendix H, point H.5 - page 53.

The abbreviations and formulae used in the text and the appendices are defined in Appendix J - page 57.

2.2.2.4 - No flames, bubbles, sweating of the bonding material, continuous squeaking, strong odours or other difficulties may occur on the brake pads during the tests.

2.3 - Validity of approval

In general, pads for disc brakes are approved for a period of 10 years, provided that no serious modifications of the requirements in this Leaflet brings their suitability into question before the end of this time.

If an RU wants to renew the approval of a pad, a corresponding application must be made 1 year before the expiry of this approval to the SG5.

A test report as specified in point 2.2.1.1 - page 8 (pads from current manufacture) must be attached to the application for renewal of the approval.

The brake pad must meet the requirements of the leaflet that is current at the time when the application is made for the renewal of approval.

Moreover in the following cases a new approval certificate must be applied for:

- major changes in the manufacturing methods or materials used for the brake pads,
- changed requirements.

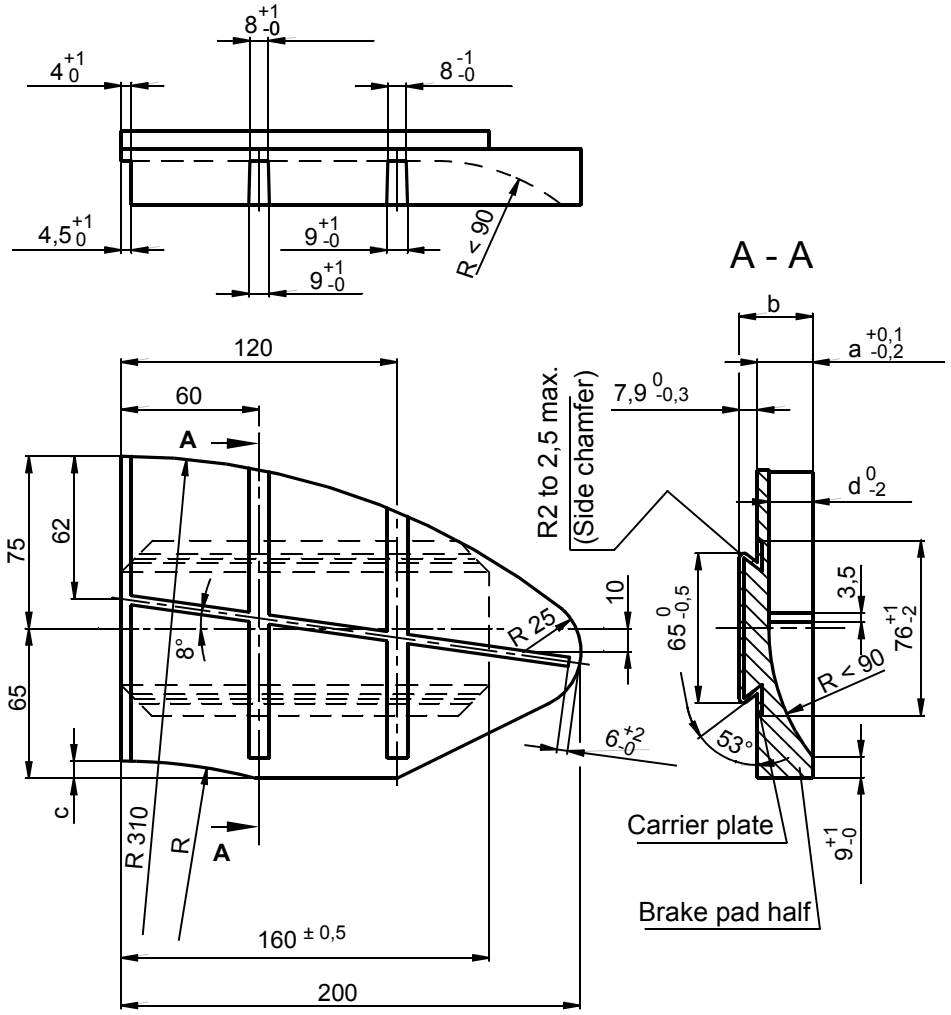
Another RU than the one that originally applied can ask to have the approval of the brake pad renewed.

The duration of the validity of the approved pads is given in Appendix I - page 56.

Appendix A - Examples of drawings of brake pads

A.1 - Brake pad half 200 cm^2 made of organic materials

View B (right hand model)

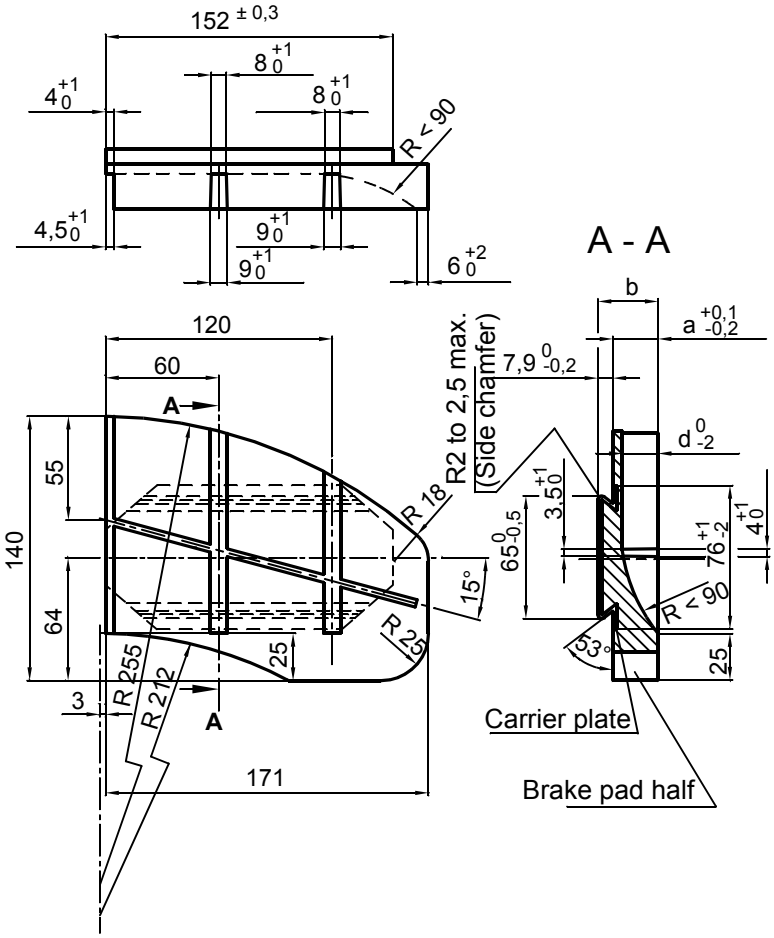


- Left hand model: same drawing but a mirror image.
- The pictorial display and the dimensions of the grooves are merely given as examples.
- For one piece pads (400 cm^2), the two halves are joined together

a	b	d	c	R
24	31,9	19	7,5	232,5
35	42,9	30	7,5	232,5
24	31,9	19	15	240
35	42,9	30	15	240

A.2 - Brake pad half 175 cm^2 made of organic materials

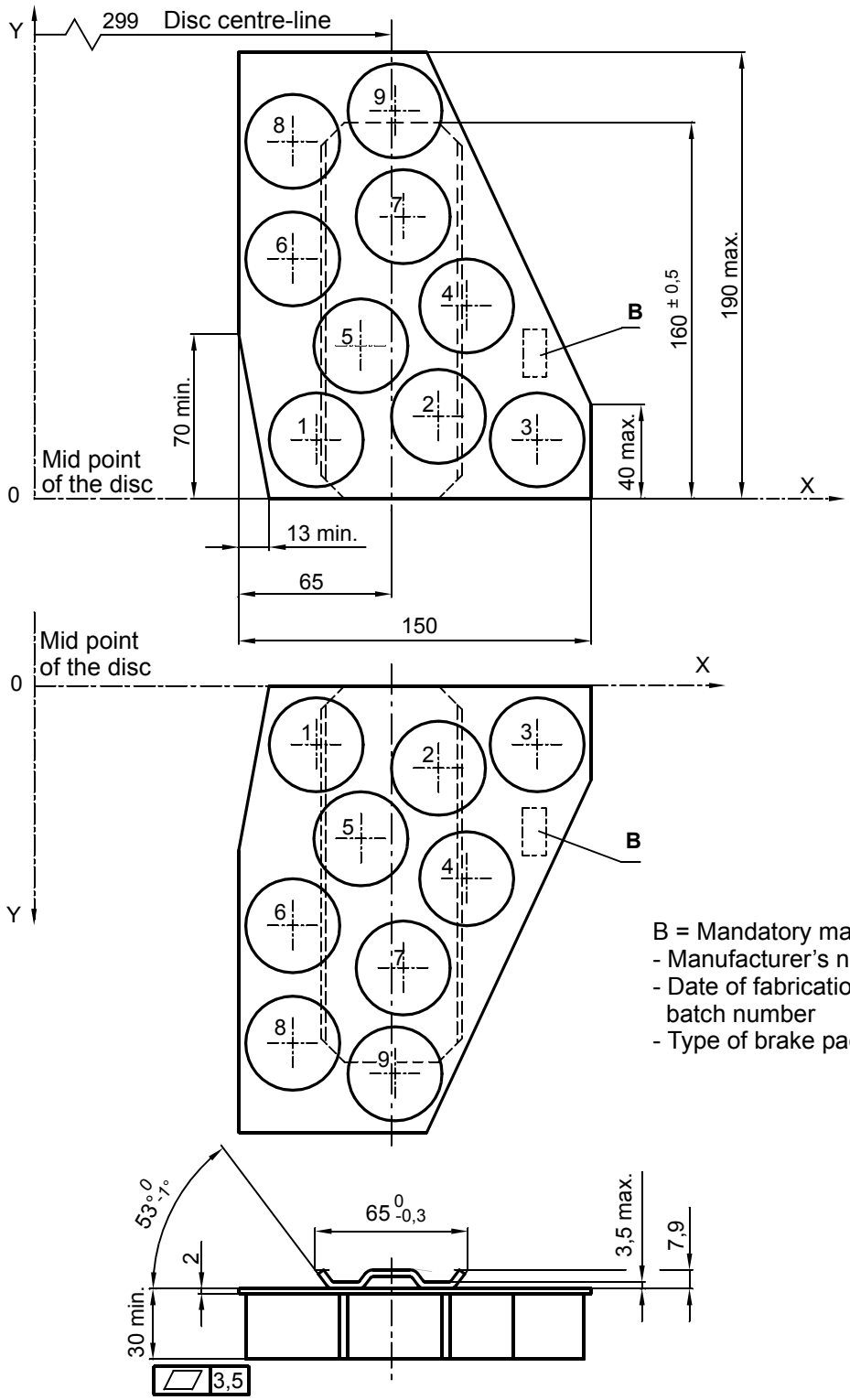
View B (right hand model)



- Left hand model: same drawing but a mirror image.
- The pictorial display and the dimensions of the grooves are merely given as examples.
- For one part pads (350 cm^2), the two halves are joined together.

a	b	d
24	31,9	19
35	42,9	30

A.3 - Brake pad halves made of sintered material, surface area 200 cm^2



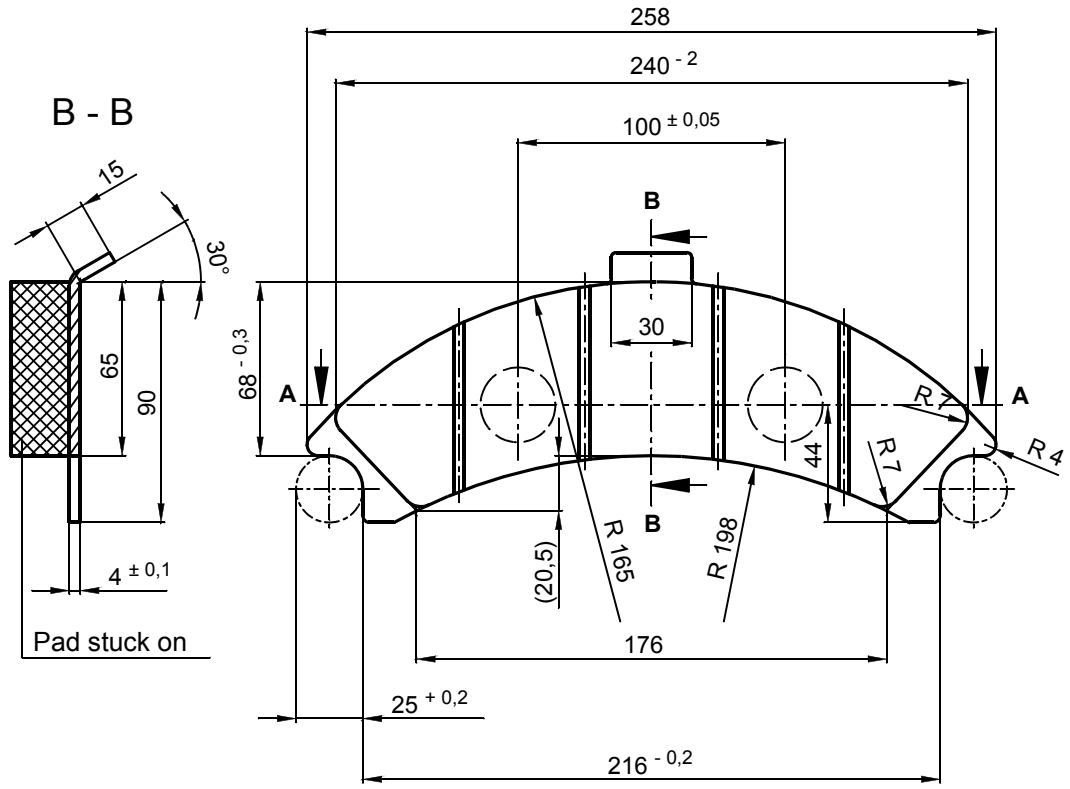
B = Mandatory marking:
- Manufacturer's name or acronym
- Date of fabrication (week and year), batch number
- Type of brake pad, material

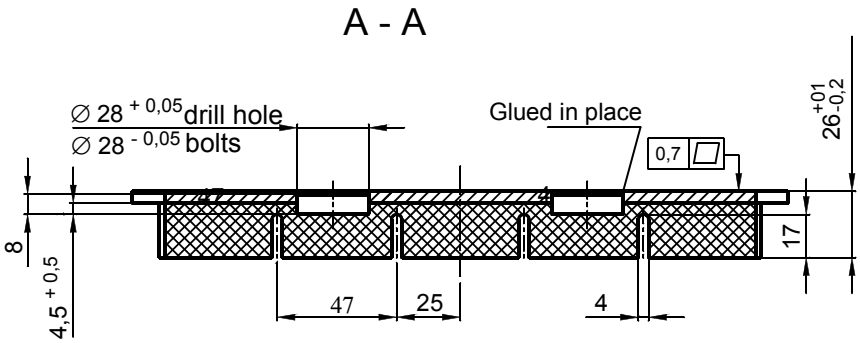
NB : The sum of the rubbing surfaces in this case is the sum of the surfaces of the nine circular shaped rubbing elements of a pad half.

A.4 - Brake pad holder for brake pads (175 cm^2 and 200 cm^2)

Reserved for two drawings

A.5 - Brake pad with a surface area of 140 cm^2





Design and measurements of the grooves should only be considered as examples

Appendix B - Requirements for organic and sintered brake pads (v_{max} = 300 km/h)

Approval of organic and sintered disc brake pads of high speed multiple unit trains (v_{max} = 300 km/h) with single stage contact pressure on the friction test bench

B.1: Test programme No. 1, v_{max} = 300 km/h

B.2: Instantaneous coefficient of friction μ_a

B.3: Average coefficient of friction μ_m

B.1 - Test programme No. 1 (v_{max} = 300 km/h)

UIC-approval for organic and sintered brake pads in high speed trains (v_{max} = 300 km/h) for a maximum energy of 13,8 [MJ] with single stage applied pressure

Pad half	composite 200 cm² (A.1 - page 11), sinter: surface area 200 cm² (A.3 - page 13)		
Brake disc	∅ 640 x 80 mm, with reduced fan capacity, made of cast iron or spheroidal graphite cast iron or steel		
Mass per brake disc	4 t	Wheel diameter	890 mm
Arrangement of the pads	H.3 - page 51		

Brake application No.	Speed v (km/h)	Force F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	22,5	20-100	x brake applications to bed-in up to at least 85% contact pattern, running in peaks on the pad must carry load. W.
1 - 12	50	15	50-60	Brake applications to a stand dry, after a cooling interval.
2 - 13	80	15	"	
3 - 14	120	15	"	
4 - 15	160	15	"	
5 - 16	200	15	"	
6 - 17	120	10	50-60	Brake applications to a stand dry, after a cooling interval.
7 - 18	160	10	"	
8 - 19	200	10	"	
9 - 20	120	22,5	50-60	Brake applications to a stand dry, after a cooling interval.
10 - 21	160	22,5	"	
11 - 22	200	22,5	"	
23	120	22,5	50-60	Standardising brake application.
24 33 42	50	15	20-30	Brake applications to a stand damp, after a cooling interval.
25 34 43	80	15	"	
26 35 44	120	15	"	
27 36 45	160	15	"	
28 37 46	200	15	"	
29 38 47	120	10	"	
30 39 48	120	22,5	"	
31 40 49	160	22,5	"	
32 41 50	200	22,5	"	
51 to 60	120	22,5	50-60	10 brake applications to dry the brake pad. W.
61	80	-	20-30	Continuous brake applications of 20 kW for 20 minutes.
62	80	15	"	Brake application to a stand dry, immediately after the continuous braking, without a cooling interval. W.
63 66 69	250	15	50-60	Between the end of brake application No. 70 and start of brake application No. 71, 2 minutes stop, then acceleration with 0,3 m/s² (E = 9,7 MJ). W.
64 67 70	250	10	"	
65 68 71	250	22,5	"	
72 75 78	270	15	50-60	Between the end of brake application No. 79 and start of brake application No. 80, 2 minutes stop, then acceleration with 0,3 m/s² (E = 11,3 MJ). W.
73 76 79	270	10	"	
74 77 80	270	22,5	"	
81 to 90	200	22,5	20-100	10 brake applications for the regeneration of the brake pads for v = 300 km/h. W.
91 94 97	300	15	50-60	Brake applications to a stand dry, after a cooling interval (E = 13,9 MJ).
92 95 98	300	10	"	
93 96 99	300	22,5	"	W.
100 102 104	320	22,5	50-60	Additional brake applications only when using sintered pads mass per disc 4.5 t; (checking the coefficient of friction with increased brake loading). W.
101 103 105	320	22	"	
106 107 108	120	15	50-60	Checking the level of the coefficient of friction.
109 to 118	200	22,5	20-100	10 brake applications to a stand dry, to regenerate the pads before the continuous braking. W.
119	80	-	20-30	Continuous braking of 30 kW for 20 minutes. Braking to a stand dry
120	80	15	-	immediately after the continuous brake application without a cooling interval. W.

Brake application time t_s = 4 ± 0,2 s. W. = weigh

Rotation and ventilation conditions

	Test bench speed (km/h)			Speed of the cooling air (km/h)	
	v	dry	wet	dry	wet
During the brake application	> 200 ≤ 200	v v	- v	v = 100 v/2	10 10
Between brake applications		100	50	80	10

Weighing

The pads shall be weighed after they have bedded-in and after brake applications No. 60, 62, 71, 80, 90, 99, 105, 118 and 120.

The actual wear of the pads shall be given for the brake applications No. 1 to 60, 61 to 62, 63 to 71, 72 to 80, 91 to 99, 100-105 and 119 to 120.

The permissible wear of the composite pads for the brake applications No. 1 to 120 (without brake applications 100 to 105) is 0,61 cm^3/MJ.

The permissible wear of the sintered pads for the brake applications No. 1 to 120 (including brake applications 100 to 105) has yet to be specified.

Interruptions

During the tests interruptions of up to 3 days before tests No. 1, 12, 23, 63, 72, 91 and 100 are allowed.

Temperatures

During the brake applications care must always be taken to see that the starting temperature has fallen to the values given.

For the brake applications No. 1, 12, 23, 63, 72, 91 and 100, a starting temperature between 20°C and 60°C is permissible.

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 25 l/h.

During wet brake applications, the spraying of the brake discs during the cooling intervals between the tests No. 23 to 50 shall not be interrupted.

After brake application No. 23, the spraying shall only begin when the brake disc temperature has reached 80°C.

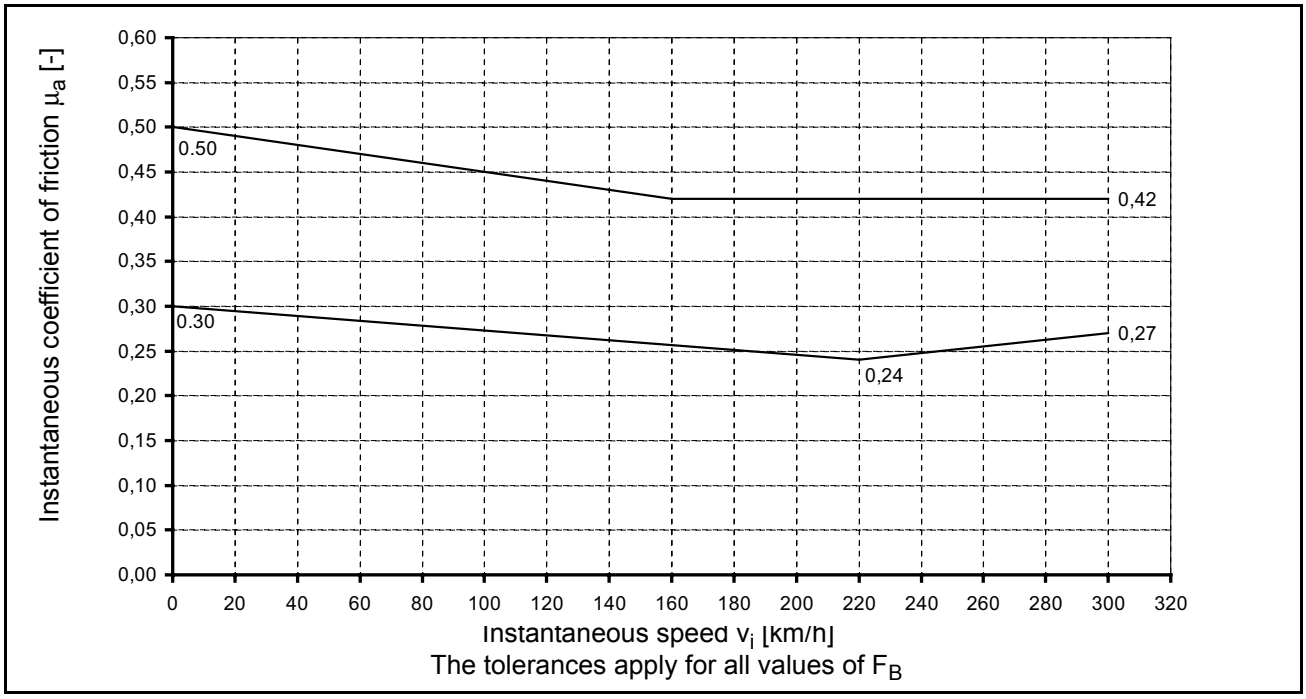
After brake application No. 50, the spraying shall be discontinued.

Further conditions

- The brake applications shall be carried out in the given sequence.
- The number of bedding-in brake applications necessary for the contact pattern of at least 85% (to remove all peaks) to be achieved shall be given in the test report.

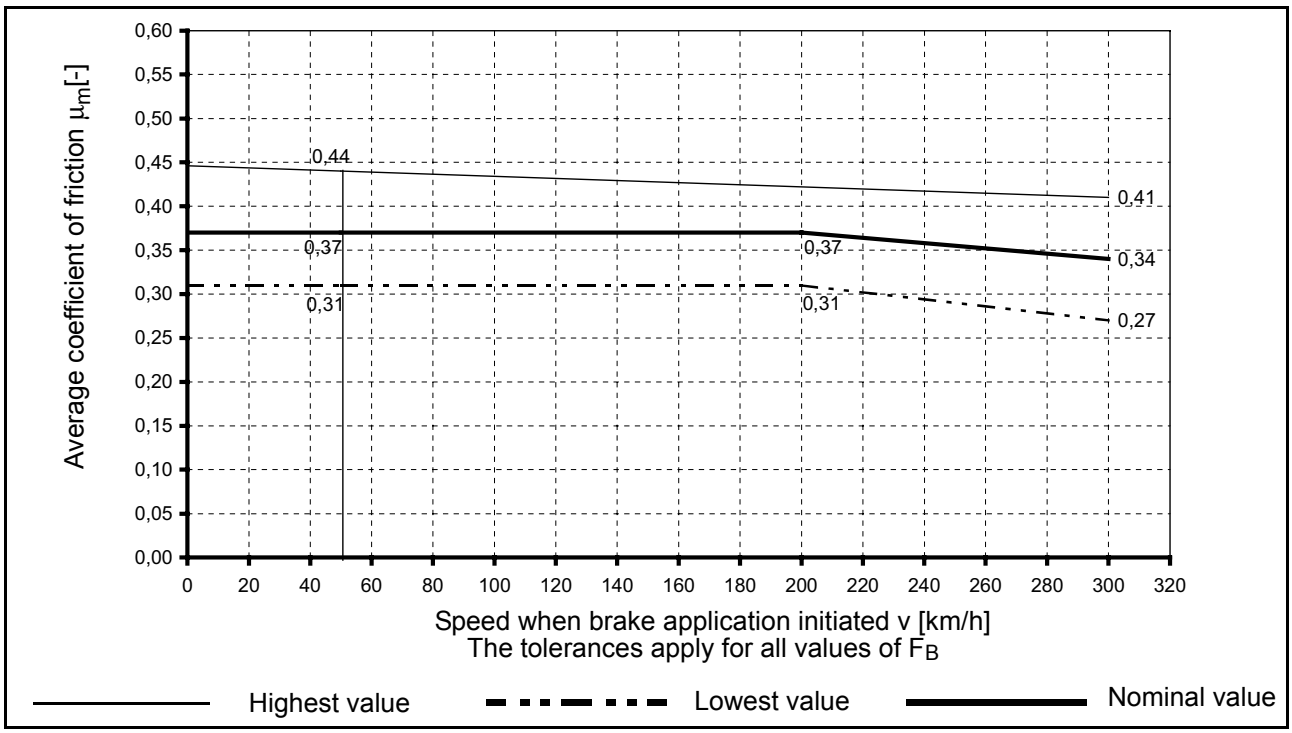
B.2 - Instantaneous coefficient of friction

Brake pads for high speed trains, for use with high energy values
Tolerances for the instantaneous coefficient of friction (μ_a) with a dry disc



B.3 - Average coefficient of friction

Brake pads for high speed trains, for use with high energy values
Tolerances for the average coefficient of friction (μ_m) with a dry disc



Appendix C - Requirements for composite brake pads for use on RIC vehicles with v_{max} = 140 and 200 km/h

Test programme for organic brake pads of passenger coaches (v_{max} = 140 and 200 km/h) on the rubbing test bench

C.1 : Test programme No. 2A, v_{max} = 140 km/h

C.2 : Test programme No. 2B, v_{max} = 200 km/h

C.3 : Test programme No. 2C, v_{max} = 200 km/h *reserved*

C.4 : Test programme No. 3A, v_{max} = 140 km/h

C.5 : Test programme No. 3B, v_{max} = 120 km/h

C.6 : Instantaneous coefficient of friction μ_a

C.7 : Average coefficient of friction μ_m

C.1 - Test programme No. 2A (v_{max} = 140 km/h)

UIC-approval for organic brake pads in passenger coaches that run at v_{max} = 140 km/h

Type	2A 1	2A 2
Pad half	200 cm^2 (A.1 - page 11)	175 cm^2 (A.2 - page 12)
Brake disc	∅ 640 x 110 mm (CI) (H.4 - page 52)	∅ 590 x 110 mm (CI) (H.4)
Mass per brake disc	7,7 t	6,2 t
Arrangement of the pads	H.3 - page 51	H.3
Wheel diameter	890 mm	880 mm

Brake application No.	Speed v (km/h)	2A 1 Force applied F_B (kN)	2A 2 Force applied F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	31	27	20-100	x brake applications to bed-in the brake pads up to at least 70% contact area. W.
1 13 25	50	31	27	50-60	Brake applications to a stand dry, after a cooling interval.
2 14 26	80	31	27	"	
3 15 27	120	31	27	"	
4 16 28	140	31	27	"	
5 17 29	50	16	14	"	
6 18 30	80	16	14	"	
7 19 31	120	16	14	"	
8 20 32	140	16	14	"	
9 21 33	50	46	40	"	
10 22 34	80	46	40	"	
11 23 35	120	46	40	"	
12 24 36	140	46	40	"	
37	120	46	40	140-150	Brake applications to a stand dry with increased initial temperature.
38	140	46	40	140-150	
39	80	46	40	210-220	
40	80	31	27	50-60	Brake applications to a stand dry, after a cooling interval.
41	80	46	40	"	W.
42	50	-	-	20-30	Continuous brake application with a dissipated load of 25 kW (2A 1) or 20 kW (2A 2) over 20 minutes.
43	50	31	27	-	Brake application to a stand immediately after continuous braking.
44	80	-	-	-	Continuous brake application immediately afterwards without a cooling interval with a dissipated power of 55 kW (2A 1) or 45 kW (2A 2) for 10 minutes.
45	80	31	27	-	Brake application to a stand immediately after continuous braking. W.
46	80	31	27	50-60	Brake applications to a stand after a cooling interval, dry.
47	120	46	40	"	
48	140	31	27	"	
49	50	16	14	20-30	Brake applications to a stand after a cooling interval, wet.
50	50	31	27	"	
51	80	31	27	"	
52	80	31	27	50-60	Brake application to a stand after a cooling interval, dry.
53	120	46	40	50-60	Brake applications to a stand after a cooling interval, dry.
54	140	31	27	"	
55	30	31	27	≤ 30	Brake applications to a stand after a cooling interval, dry.
56	30	31	27	"	
57	30	31	27	"	W.

Brake application time t_s = 4 ± 0,2 s.

W. = weigh

Rotation and ventilation conditions

	Test bench speed (km/h)		Speed of the cooling air (km/h)	
	dry	wet	dry	wet
During the brake application	v	v	v/2	10
Between brake applications	100	50	80	10

Weighing

The pads shall be weighed after they have been bedded-in and after brake applications No. 41, 45 and 57.

The actual wear of the pads shall be given for the brake applications No. 1 to 41 and 42 to 45.

The permissible wear of the pads for the brake applications No. 1 to 57 is 0,28 cm^3/MJ.

Interruptions

During the tests interruptions of up to 3 days before tests No. 1, 13, 25, 42 and 46 are allowed.

Temperatures

During the brake applications care must always be taken to see that the starting temperature has fallen to the value given.

For the brake applications No. 1, 13, 25 and 46 a starting temperature between 20°C and 60°C is permissible.

The brake applications to a stand which immediately follow the gradient brake applications shall be carried out with the temperatures which were produced at the end of these gradient brake applications (tests No. 43 and 45). The continuous brake application No. 44 which follows the brake application to a stand No. 43 shall be done immediately afterwards without a cooling interval.

If, during the gradient brake applications, the arithmetic average of the brake disc temperatures of 6 measuring positions reaches 375°C, the brake application shall immediately be interrupted (check the coefficient of friction and the mechanical properties of the brake pads).

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 6 cm^3/cm^2 of the rubbing surface covered per hour (25 l/h for brake discs of 640 mm and 21 l/h for brake discs of 590 mm dia).

During wet brake applications, the spraying of the brake disc during the cooling intervals between the tests No. 48 to 51 shall not be interrupted.

After brake application No. 48, the spraying shall only begin when the brake disc temperature has reached 80°C.

After brake application No. 51, the spraying shall be discontinued.

Further conditions

- The brake applications shall be carried out in the given sequence.
- The number of bedding-in brake applications necessary for a contact pattern of at least 70% to be achieved shall be given in the test report.

C.2 - Test programme No. 2B (v_{max} = 200 km/h)

UIC-approval for organic brake pads in passenger coaches that run at v_{max} = 200 km/h

Type	2B 1	2B 2
Pad half	organic 200 cm^2 (A.1 - page 11)	organic 175 cm^2 (A.2 - page 12)
Brake disc	∅ 640 x 110 mm (CI) (H.4 - page 52)	∅ 590 x 110 mm (CI) (H.4)
Mass per brake disc	6,7 t	5,7 t
Arrangement of the pads	H.3 - page 51	H.3
Wheel diameter	890 mm	880 mm

Brake application No.	Speed v (km/h)	2B 1 Force applied F_B (kN)	2B 2 Force applied F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	28	25	20-100	x brake applications to bed-in the brake pads up to at least 70% contact area. W.
1 19 37	50	28	25	50-60	Brake applications to a stand dry, after a cooling interval.
2 20 38	80	28	25	"	
3 21 39	120	28	25	"	
4 22 40	140	28	25	"	
5 23 41	160	28	25	"	
6 24 42	200	28	25	"	
7 25 43	50	16	14	"	
8 26 44	80	16	14	"	
9 27 45	120	16	14	"	
10 28 46	140	16	14	"	
11 29 47	160	16	14	"	
12 30 48	200	16	14	"	
13 31 49	50	40	36	"	
14 32 50	80	40	36	"	
15 33 51	120	40	36	"	
16 34 52	140	40	36	"	
17 35 53	160	40	36	"	
18 36 54	200	40	36	"	
55	140	40	36	140-150	Brake applications to a stand dry with increased initial temperature.
56	200	40	36	140-150	
57	80	40	36	210-220	
58	80	28	25	50-60	Brake applications to a stand dry, after a cooling interval. W.
59	80	40	36	"	
60 63 66	200	28	25	50-60	Brake applications to a stand dry, after a cooling interval, mass per disc m = 7,7 t or m = 6,2 t (see test conditions for details). W.
61 64 67	200	16	14	"	
62 65 68	200	40	36	"	
69	50	-	-	20-30	Continuous brake application with a dissipated load of 25 kW (2B 1) or 20 kW (2B 2) over 20 minutes.
70	50	28	25	-	Brake application to a stand immediately after continuous braking.
71	80	-	-	-	Continuous brake application immediately afterwards without a cooling interval with a dissipated power of 55 kW (2B 1) or 45 kW (2B 2) for 10 minutes.
72	80	28	25	-	Brake application to a stand immediately after continuous braking. W.
73	80	28	25	50-60	Brake applications to a stand after a cooling interval, dry.
74	120	40	36	"	
75	200	28	25	"	
76	50	16	14	20-30	Brake applications to a stand after a cooling interval, wet.
77	50	28	25	"	
78	80	28	25	"	
79	80	28	25	50-60	Brake application to a stand after a cooling interval, dry.
80	120	40	36	50-60	Brake applications to a stand after a cooling interval, dry.
81	200	28	25	"	
82	30	28	25	≤ 30	Brake applications to a stand after a cooling interval, dry.
83	30	28	25	"	
84	30	28	25	"	W.

Brake application time t_s = 4 ± 0,2 s.

W. = weigh

Rotation and ventilation conditions

	Test bench speed (km/h)		Speed of the cooling air (km/h)	
	dry	**wet**	**dry**	**wet**
During the brake application	v	v	v/2	10
Between brake applications	100	50	80	10

Weighing

The pads shall be weighed after they have been bedded-in and after brake applications No. 59, 68, 72 and 84.

The actual wear of the pads shall be given for the brake applications No. 1 to 59, 60 to 68 and 69 to 72.

The permissible wear of the pads for the brake applications No. 1 to 84 is 0,55 cm^3/MJ

Interruptions

During the tests interruptions of up to 3 days before tests No. 1, 19, 37, 60, 69 and 73 are allowed.

Temperatures

During the brake applications, care must always be taken to see that the starting temperature has fallen to the values given.

For the brake applications No. 1, 19, 37, 60 and 73 a starting temperature between 20°C and 60°C is permissible.

The brake applications to a stand which immediately follow continuous braking shall be carried out with the temperature which was produced at the end of this continuous braking (no cooling interval between tests No. 69, 70 and 71). The continuous brake application No. 71, which follows the brake application to a stand No. 70 shall be done immediately after this without a cooling interval.

If during the continuous braking the arithmetic average of the brake disc temperature of the 6 measuring places reaches 375°C, the braking shall be interrupted immediately (check of the coefficient of friction and the mechanical properties of the brake pads).

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 25 l/h for 640 mm dia brake discs and 21 l/h for 590 mm brake discs. During wet brake applications the spraying of the brake discs during the cooling intervals between the tests No. 76 to 78 shall not be interrupted.

After brake application No. 75, the spraying shall only begin when the brake disc temperature has reached 80°C.

After brake application No. 78, the spraying shall be discontinued.

Further conditions

- The brake applications shall be carried out in the given sequence.

- The number of bedding-in brake applications necessary for the contact pattern of at least 70% (to remove all peaks) to be achieved shall be given in the test report.

For the exceptional case of the brake applications No. 60 to 68, masses and speed shall be so adjusted that in each case an energy of 11,9 MJ and 9,6 MJ is converted (in this case it is allowed to exceed the limit for the correction factor K).

C.3 - Test programme No. 2C (v_{max} = 200 km/h, multiple unit trains with wheel brake discs)

reserved

C.4 - Test programme No. 3A (wet tests)

UIC-approval for organic brake pads used in passenger coaches (v_{max} = 140 km/h and 200 km/h), wagons (v_{max} = 160 km/h) and high speed trains (v_{max} = 300 km/h) under wet conditions

Type	3A 1	3A 2
Pad half	organic: 200 cm^2 (A.1 - page 11) or sintered: area covered 200 cm^2 (A.3 - page 13)	organic: 175 cm^2 (A.2 - page 12)
Brake disc	∅ 640 x 110 mm (CI), or ∅ 610 x 110 mm (CI), or ∅ 640 x 80 mm (spheroidal graphite cast iron or cast steel) (H.4 - page 52), or ∅ 640 x 45 mm (unventilated; cast steel)	∅ 590 x 110 mm (CI) or ∅ 610 x 110 m (CI) (H.4)
Mass per brake disc	4,7 t	4,7 t
Arrangement of the pads	H.3 - page 51	H.3
Wheel diameter	890 mm	880 mm

Brake application No.	Speed v (km/h)	3A 1 Force applied F_B (kN)	3A 2 Force applied F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	26	23	20-100	x brake applications to bed-in the brake pads up to at least 85% contact area, projecting pad peaks must be removed.
1 8	80	21	18	50-60	Brake applications to a stand dry, after a cooling interval.
2 9	120	16	14	"	
3 10	120	21	18	"	
4 11	140	21	18	"	
5 12	80	26	23	"	
6 13	120	26	23	"	
7 14	140	26	23	"	
15 22 29	80	21	18	20-30	Brake applications to a stand wet, after a cooling interval. Water quantity: 25 l/h for brake discs ∅ 640 mm 23 l/h for brake discs ∅ 610 mm 21 l/h for brake discs ∅ 590 mm
16 23 30	120	16	14	"	
17 24 31	120	21	18	"	
18 25 32	140	21	18	"	
19 26 33	80	26	23	"	
20 27 34	120	26	23	"	
21 28 35	140	26	23	"	

Brake application time $t_s = 4 \pm 0{,}2$ s.

Rotation and ventilation conditions

	Test bench speed (km/h)		Speed of the cooling air (km/h)	
	dry	wet	dry	wet
During the brake application	v	v	v/2	10
Between brake applications	100	50	80	10

Interruptions

During the tests, interruptions of up to 3 days before tests No. 1, 8, and 15 are allowed.

If there is an interruption before the test No. 15, an identical brake application No. 14 shall be carried out in addition outside the programme in order to observe the conditions for spaying water.

Temperatures

During the brake applications, care must always be taken to see that the starting temperature has fallen to the value given.

For the brake applications No. 1 and 8 a starting temperature between 20°C and 60°C is permissible.

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 25 l/h for brake discs of 640 mm, 23 l/h for brake discs of 610 mm dia and 21 l/h for brake discs of 590 mm dia. During wet brake applications the spraying of the brake discs during the cooling intervals between the tests No. 15 and 35 shall not be interrupted.

After brake application No. 14, the spraying shall only begin when the brake disc temperature has reached 80°C.

Further conditions

- The brake applications shall be carried out in the given sequence.
- The number of bedding-in brake applications necessary for the contact pattern of at least 85% to be achieved (all the projecting pad peaks) shall be given in the test report.

C.5 - Test programme No. 3B (severe winter conditions)

UIC-approval for organic brake pads under severe winter conditions (temperature under 0°C, heavy drifting snow)

Type	3B 1	3B 2
Pad half	organic: 200 cm^2 (A.1 - page 11)	organic: 175 cm^2 (A.2 - page 12)
Brake disc	Internally ventilated, cast iron, cast steel or spheroidal graphite cast iron (one piece rubbing ring with no grooves and not divided into segments)	
	∅ 640 x 110 mm (CI), or ∅ 610 x 110 mm (CI), or ∅ 640 x 80 mm (spheroidal graphite cast iron or cast steel) (H.4 - page 52)	∅ 590 x 110 mm, ∅ 610 x 110 m (H.4)
Mass per brake disc	4,2 t	4,2 t
Arrangement of the pads	H.3 - page 51	H.3
Wheel diameter	890 mm	880 mm

Brake application No.	Speed v (km/h)	3B 1 Force applied F_B (kN)	3B 2 Force applied F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	25	22	20-100	x brake applications to bed-in the brake pads up to at least 85% contact area, projecting pad peaks must be removed.
1 7	80	25	22	50-60	Brake applications to a stand dry, after a cooling interval.
2 8	120	12	11	"	
3 9	120	25	22	"	
4 10	120	25	22	"	
5 11	80	12	11	"	
6 12	80	12	11	"	
13 19 25	80	25	22	15-20	Brake applications to a stand wet, after a cooling interval.
14 20 26	120	12	11	"	
15 21 27	120	25	22	"	
16 22 28	120	25	22	"	
17 23 29	80	12	11	"	
18 24 30	80	12	11	"	
31	80	25	22	50-60	Brake applications to a stand dry, after a cooling interval.
32	80	25	22	"	
33	80	25	22	"	
34	80	25	22	"	
35	80	25	22	"	
36 41	80	25	22	50-60	Brake applications to a stand wet, after a cooling interval.
37 42	80	25	22	"	
38 43	80	25	22	"	
39 44	80	25	22	"	
40 45	80	25	22	"	

Brake application time $t_s = 4 \pm 0{,}2$ s.

To condition the brake discs before the start of tests with a new type of pad, the brake applications No. 1-12 of the test programme should be carried out at least three times.

Rotation and ventilation conditions

	Test bench speed (km/h)		Speed of the cooling air (km/h)	
	dry	**wet**	**dry**	**wet**
During the brake application	v	v	v/2	10
Between brake applications	100	50	80	10

Interruptions

During the tests, interruptions of up to 3 days before tests No. 1, 7, and 13 are allowed.

If there is an interruption before the test No. 13, an identical brake application No. 12 shall be carried out in addition outside the programme in order to observe the conditions for spaying water.

Temperatures

During the brake applications, care must always be taken to see that the starting temperature has fallen to the value given.

For the brake applications No. 1 and 7 a starting temperature between 20°C and 60°C is permissible.

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 45 l/h for brake discs of 640 mm, 42 l/h for brake discs of 610 mm dia and 38 l/h for brake discs of 590 mm dia. During wet brake applications the spraying of the brake discs during the cooling intervals between the tests No. 13 to 30 and 36 to 45 shall not be interrupted.

After brake application No. 12 and 35, the spraying shall only begin when the brake disc temperature has reached 80°C.

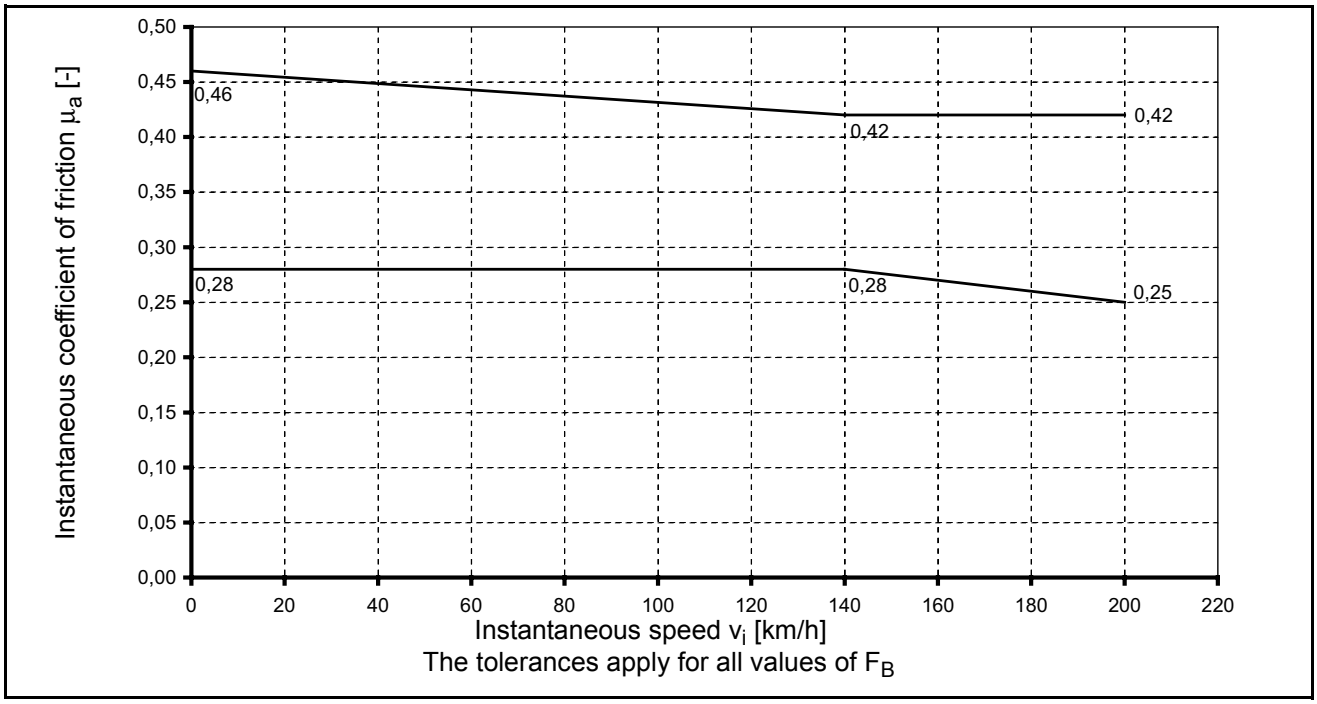
In order to avoid unnecessarily long cooling times of the brake disc, the water temperature should be between 10°C and 15°C.

Further conditions

- The brake applications shall be carried out in the given sequence.
- The number of bedding-in brake applications necessary for the contact pattern of at least 85% to be achieved (projecting pad peaks must carry load) shall be given in the test report.

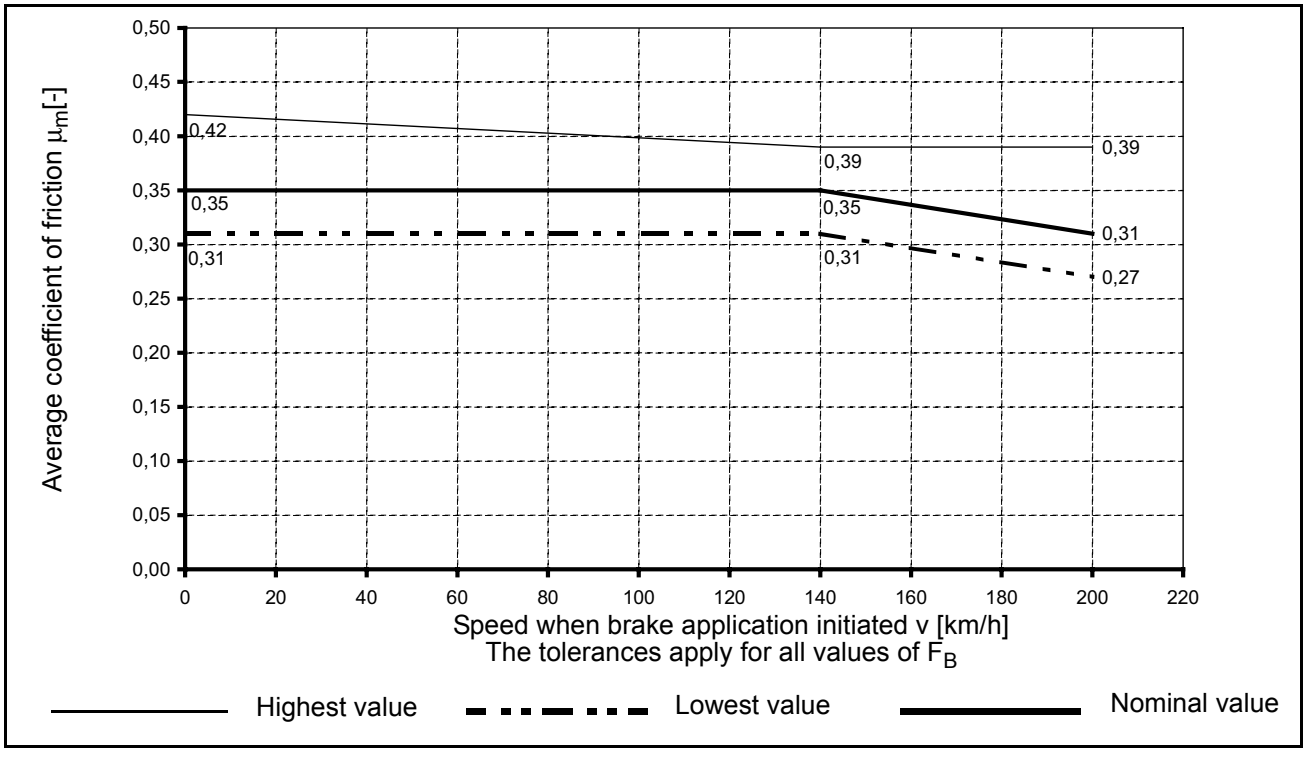
C.6 - Instantaneous coefficient of friction

Tolerances for the instantaneous coefficient of friction (μ_a) with a dry disc



C.7 - Average coefficient of friction

Tolerances for the average coefficient of friction (μ_m) with dry disc



Appendix D - Requirements for brake pads for freight wagons

Requirements for brake pads for freight wagons (v_{max} = 160 km/h) on the friction test bench

D.1:	Test programme No. 4A, Loaded wagon	*reserved*
D.2:	Test programme No. 4B, Empty wagon	*reserved*
D.3:	Test programme No. 4C, Loaded low floor wagon	*reserved*
D.4:	Test programme No. 4D, Empty low floor wagon	*reserved*
D.5.	Instantaneous coefficient of friction μ_a	*reserved*
D.6:	Average coefficient of friction μ_m	*reserved*

Appendix E - Requirements for sintered brake pads, v_{max} = 300 km/h, two stage pressure

Requirements for sintered brake pads for high speed multiple unit trains (v_{max} = 300 km/h) with two stage pressure on the friction test bench

E.1 : Test programme No. 5, v_{max} = 320 km/h

E.2 : Instantaneous coefficient of friction μ_a

E.3 : Average coefficient of friction μ_m

E.1 - Test programme No. 5

UIC-approval of sintered brake pads in high speed multiple unit trains that run at v_{max} = 320 km/h and have a two stage pressure system (maximum energy 17,8 MJ)

Pad half	sintered (surface area 200 cm^2) (A.3 - page 13)		
Brake disc	Ø 640 mm, thickness 45 mm (not ventilated) or 80 mm (reduced fan capacity), made of alloyed steel		
Mass per brake disc	4 t for v ≤ 300 km/h and 4,5 t for v = 320 km/h (17,8 MJ)		
Arrangement of the pads	H.3 - page 51	Wheel diameter	890 mm

Brake application No.	Speed v (km/h)	Force F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	25	20-100	x brake applications to bed-in the brake pads up to at least 85% contact area (the leading edges of the rubbing element must be in contact). W.
1 12	50	18	50-60	Brake applications to a stand dry, after a cooling interval.
2 13	80	18	"	
3 14	120	18	"	
4 15	160	18	"	
5 16	200	18	"	
6 17	120	8	50-60	Brake applications to a stand dry, after a cooling interval.
7 18	160	8	"	
8 19	200	8	"	
9 20	120	25	50-60	Brake applications to a stand dry, after a cooling interval.
10 21	160	25	"	
11 22	200	25	"	
23	120	25	50-60	Initialisation brake application.
24 33 42	50	18	20-30	Brake applications to a stand after a cooling interval, wet.
25 34 43	80	18	"	
26 35 44	120	18	"	
27 36 45	160	18	"	
28 37 46	200	18	"	
29 38 47	120	8	"	
30 39 48	120	25	"	
31 40 49	160	25	"	
32 41 50	200	25	"	
51 to 55	120	25	50-60	5 brake applications to a stand dry, to dry the pads. W.
56	80	-	20-30	Continuous brake application at 20 kW for 20 minutes.
57	80	18	-	Brake application to a stand dry, carried out immediately after the continuous brake application without cooling interval. W.
58 to 62	120	25	50-60	5 brake applications to clean the disc.
63 66 69	220	18	50 - 60	Between the end of brake application No. 70 and the start of brake application No. 71, 2 minutes stop, then acceleration at a = 0,3 m/s^2 and immediate brake application (E = 7,5 MJ). W.
64 67 70	220	8	"	
65 68 71	220	25	"	
		F_{B1} / F_{B2} [a]		Between the end of brake application No. 76 and the start of brake application No. 77, 2 minutes stop, then acceleration at a = 0,3 m/s^2 and immediate brake application (E = 9,6 MJ) W.
72 74 76	250	14/18	50 - 60	
73 75 77	250	19/25	"	
		F_{B1} / F_{B2} [a]		Between the end of brake application No 82 and the start of brake application No. 83, 2 minutes stop, then acceleration at a = 0,3 m/s^2 and immediate brake application (E = 13,9 MJ) W.
78 80 82	300	14/18	50 - 60	
79 81 83	300	19/25	"	
		F_{B1} / F_{B2} [a]		Mass per disc: 4,5 t to check the validity with a not unusual overloading, corresponding to an energy of E = 17,8 MJ. W.
84 86 88	320	14/18	50 - 60	
85 87 89	320	19/25	"	
90 91 92	120	18	50-60	Checking the level of the coefficient of friction. W.
93	80	-	20-30	Continuous braking at 30 kW for 20 minutes. Brake application to a stand dry, immediately after the continuous brake application, without a cooling interval. W.
94	80	18	-	

Brake application time t_s = 4 ± 0,2 s.

a. F_B in two stages: F_{B1} from v to 215 km/h and F_{B2} from 215 to 0 km/h.

Rotation and ventilation conditions

	Test bench speed (km/h)			Speed of the cooling air V_R (km/h)	
	v	**dry**	**wet**	**dry**	**wet**
During the brake application	> 200 ≤ 200	v v	- v	v = 100 v/2	10 10
Between brake applications		100	50	80	10

Weighing

The pads shall be weighed after they have been bedded-in and after brake applications No. 55, 57, 71, 77, 83, 89, 92 and 94.

The actual wear of the pads shall be given for the brake applications No. 56 to 57, 58 to 71, 72 to 77, 78 to 83, 84 to 89 and 93 to 94.

The permissible wear of the pads for the brake applications No. 1 to 94 is 0,35 cm^3/MJ.

Interruptions

During the tests, interruptions of up to 3 days before tests No. 1, 12, 23, 63, 72, 78 and 84 are allowed.

Temperatures

During the brake applications, care must always be taken to see that the starting temperature has fallen to the values given.

For the brake applications No. 1, 12, 23, 62, 71, 77 and 83 a starting temperature between 20°C and 60°C is permissible.

Those brake applications to a stand which follow immediately after the continuous brake applications shall be carried out with the temperature which is present at the end of the continuous brake application (no cooling interval before brake applications No. 57 and 94).

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 25 l/h.

During wet brake applications the spraying of the brake discs during the cooling intervals between the tests No. 23 to 50 shall not be interrupted.

After brake application No. 23, the spraying shall only begin when the brake disc temperature has reached 80°C.

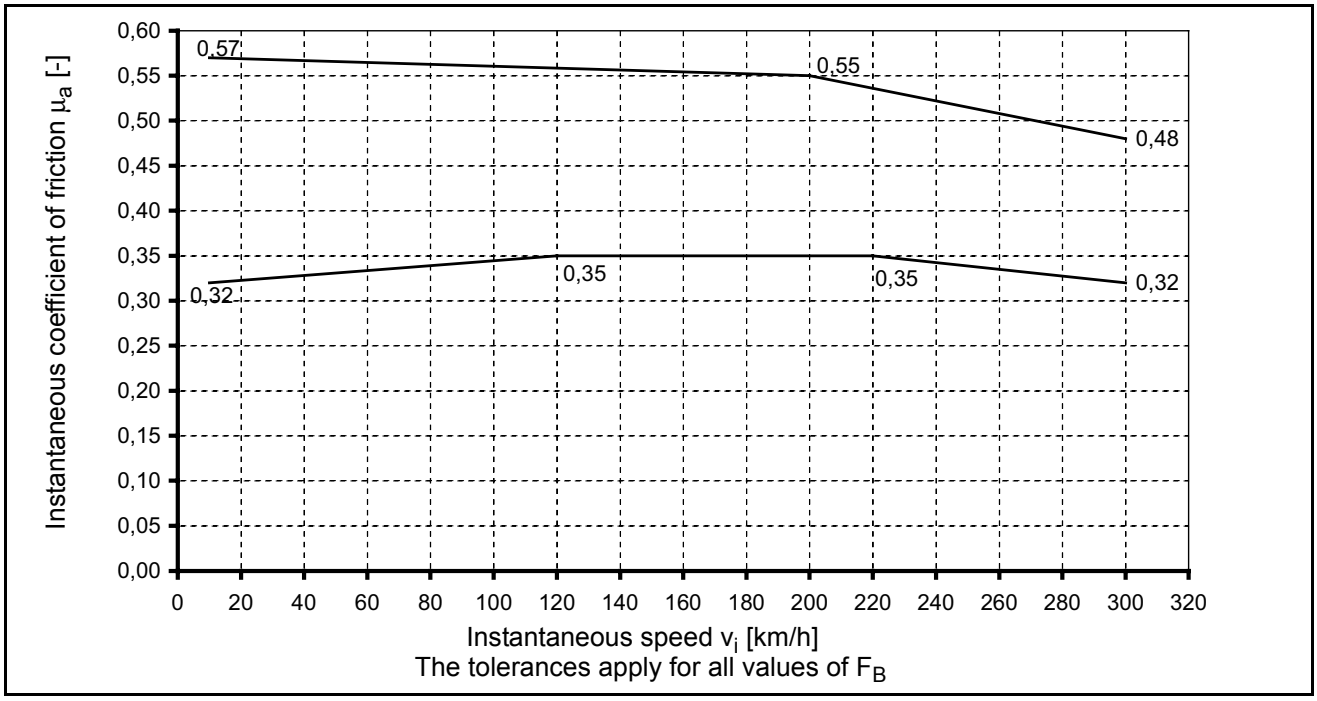
After brake application No. 50, the spraying shall be discontinued.

Further conditions

- The brake applications shall be carried out in the given sequence.
- The number of bedding-in brake applications necessary for the contact pattern of at least 85% (all leading edges of the rubbing elements) to be achieved shall be given in the test report.
- In the brake applications No. 84 to 89 the coefficients of friction shall be checked with a not unusual overload corresponding to an energy of 17,8 MJ. This energy shall be simulated with 4,5 t and 320 km/h and corresponds at 300 km/h to a braked mass per disc of about 5,1 t.

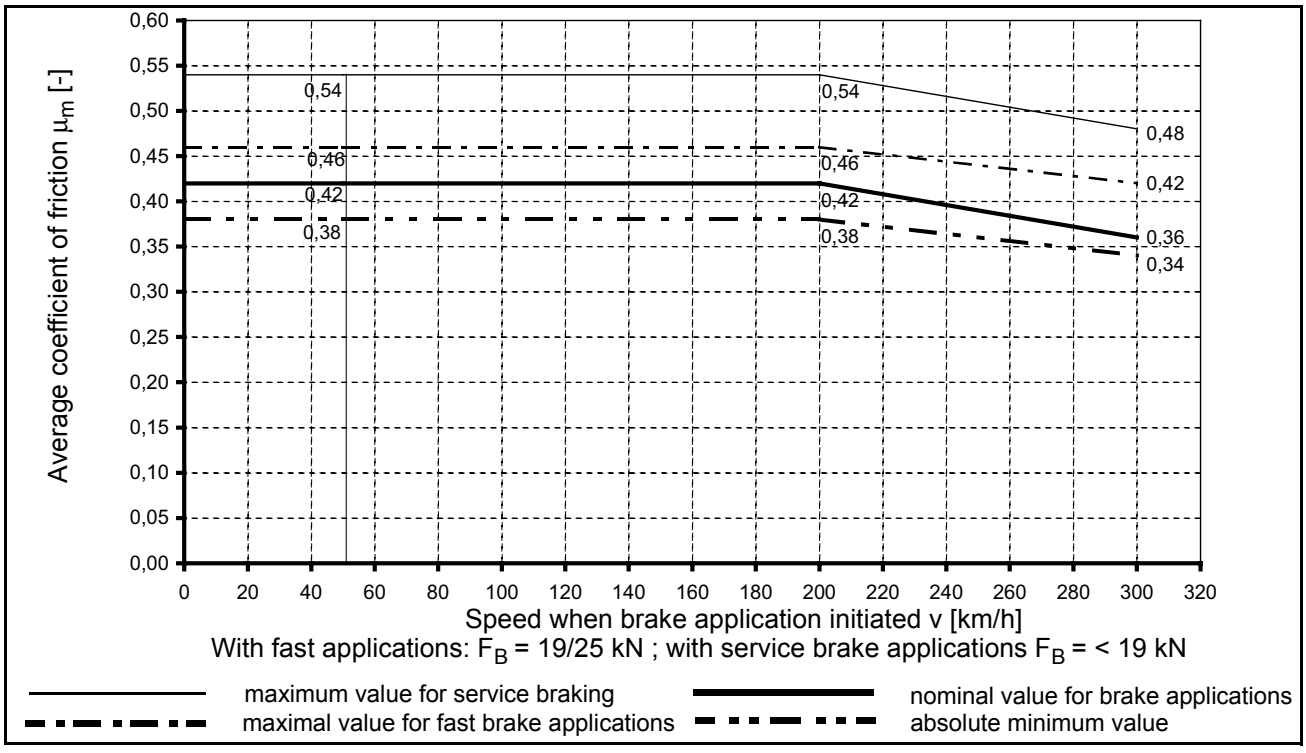
E.2 - Instantaneous coefficient of friction

Tolerances for the instantaneous coefficient of friction (μ_a) with a dry disc, brake pads for high speed trains, use with very high energy values



E.3 - Average coefficient of friction

Tolerances for the average coefficient of friction (μ_m) with a dry disc, brake pads for high speed trains, use with very high energy values



Appendix F - Requirements for sintered brake pads for passenger coaches (v_{max} = 200 km/h)

Requirements for sintered brake pads for passenger coaches (v_{max} = 200 km/h) on the friction test bench

F.1 : Test programme No. 6A, v_{max} = 200 km/h

F.2 : Test programme No. 6B, v_{max} = 140 km/h

F.3 : Test programme No. 6C, v_{max} = 200 km/h (wheel brake discs) *reserved*

Instantaneous coefficient of friction μ_a (see Appendix C , point C.6 - page 31)

Average coefficient of friction μ_m (see Appendix C , point C.7 - page 31)

F.1 - Test programme No. 6A

UIC-approval for sintered brake pads for passenger coaches that run at v_{max} = 200 km/h

Pad half	sintered (surface area 200 cm^2 - A.3 - page 13)
Brake disc	Ø 640 x 110 mm cast steel or Ø 640 x 110 mm cast steel, ventilated (H.4 - page 52)
Mass per brake disc	7,7 t
Arrangement of the pads	H.3 - page 51
Wheel diameter	890 mm

Brake application No.	Speed v (km/h)	Force F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	31	20-100	x brake applications to bed-in the brake pads up to at least 70% contact area. W.
1 19 37	50	31	50-60	Brake applications to a stand dry, after a cooling interval.
2 20 38	80	31	"	
3 21 39	120	31	"	
4 22 40	140	31	"	
5 23 41	160	31	"	
6 24 41	200	31	"	
7 25 43	50	16	"	
8 26 44	80	16	"	
9 27 45	120	16	"	
10 28 46	140	16	"	
11 29 47	160	16	"	
12 30 48	200	16	"	
13 31 49	50	46	"	
14 32 50	80	46	"	
15 33 51	120	46	"	
16 34 52	140	46	"	
17 35 53	160	46	"	
18 36 54	200	46	"	
55	140	46	140-150	Brake applications to a stand dry, with raised initial temperatures.
56	200	46	140-150	
57	80	46	210-220	
58	80	31	50-60	Brake applications to a stand dry, after a cooling interval.
59	80	46	"	W.
60 63 66	200	31	50-60	Brake applications to a stand dry, after a cooling interval.
61 64 67	200	16	"	Mass per disc m = 8,5 t (see test conditions for details).
62 65 68	200	46	"	W.
69	50	-	20-30	Continuous brake application with 25 kW for 24 minutes.
70	50	31	-	Brake application to a stand immediately following the continuous braking.
71	80	-	-	Continuous brake application immediately afterwards, 55 kW for 10 minutes.
72	80	31	-	Brake application to a stand immediately after the continuous braking. W.
73	80	31	50-60	Brake applications to a stand dry, after a cooling interval.
74	120	46	"	
75	200	31	"	
76	50	16	20-30	Brake applications to a stand wet, after a cooling interval
77	50	31	"	
78	80	31	"	
79	80	31	50-60	Brake application to a stand dry, after a cooling interval.
80	120	46	50-60	Brake applications to a stand dry, after a cooling interval.
81	200	31	"	
82	30	31	≤ 30	Brake applications to a stand dry, after a cooling interval.
83	30	31	"	
84	30	31	"	W.

Brake application time t_s = 4 ± 0,2 s.

W. = weigh

Rotation and ventilation conditions

	Test bench speed (km/h)		Speed of the cooling air (km/h)	
	dry	wet	dry	wet
During the brake application	v	v	v/2	10
Between brake applications	100	50	80	10

Weighing

The pads shall be weighed after they have been bedded-in and after brake applications No. 59, 68, 72 and 84.

The actual wear of the pads shall be given for the brake applications No. 1 to 59, 60 to 68 and 69 to 72.

The permissible wear of the pads for the brake applications No. 1 to 84 is 0,35 cm^3/MJ.

Interruptions

During the tests, interruptions of up to 3 days before tests No. 1, 19, 37, 60, 69 and 73 are allowed.

Temperatures

During the brake applications, care must always be taken to see that the starting temperature has fallen to the values given.

For the brake applications No. 1, 19, 37, 60 and 73, a starting temperature between 20°C and 60°C is permissible.

The brake applications to a stand which immediately follow continuous braking shall be carried out with the temperature which was produced at the end of this continuous braking (no cooling interval between tests No. 70 and 72). The continuous brake application No 71, which follows the brake application to a stand No. 70 shall be done immediately after this without a cooling interval.

If during the continuous braking the arithmetic average of the brake disc temperature of the 6 measuring places reaches 450°C, the braking shall be interrupted immediately.

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 23 l/h for 610 mm dia brake discs and 25 l/h for 640 mm brake discs. During wet brake applications the spraying of the brake discs during the cooling intervals between the tests No. 76 to 78 shall not be interrupted.

After brake application No. 75, the spraying shall only begin when the brake disc temperature has reached 80°.

After brake application No. 78, the spraying shall be discontinued.

Further conditions

- The brake applications shall be carried out in the given sequence.

- The number of bedding-in brake applications necessary for a contact surface of at least 70% to be achieved shall be given in the test report.

For the exceptional case of the brake applications No. 60 to 68, masses and speed shall be so adjusted that in each case an energy of 13,1 MJ is converted (in this case it is allowed to exceed the limits for the correction factor K).

F.2 - Test programme No. 6B (wet tests)

UIC-approval programme for sintered brake pads for passenger coaches which run at v_{max} = 200 km/h under wet conditions

Pad half	sintered pad (surface area 200 cm^2 - A.3 - page 13)
Brake disc	∅ 610 x 110 mm cast steel ventilated or ∅ 640 x 110 mm cast steel ventilated (H.4 - page 52)
Mass per brake disc	5,7 t
Arrangement of the pads	H.3 - page 51
Wheel diameter	890 mm

Brake application No.	Speed v (km/h)	Force F_B (kN)	Initial temperature θ_0 (°C)	Remarks
R1 to Rx	120	30	20-100	x brake applications to bed-in the pads in order to get a contact area of at least 85%. Leading edges of the rubbing units must carry load.
1 8	80	21	50-60	Brake applications to a stand dry, after a cooling interval.
2 9	120	12	"	
3 10	120	21	"	
4 11	140	21	"	
5 12	80	30	"	
6 13	120	30	"	
7 14	140	30	"	
15 22 29	80	21	20-30	Brake applications to a stand wet, after a cooling interval
16 23 30	120	12	"	
17 24 31	120	21	"	
18 25 32	140	21	"	
19 26 33	80	30	"	
20 27 34	120	30	"	
21 28 35	140	30	"	

Brake application time $t_s = 4 \pm 0,2$ s.

Rotation and ventilation conditions

	Test bench speed (km/h)		Speed of the cooling air (km/h)	
	dry	wet	dry	wet
During the brake application	v	v	v/2	10
Between brake applications	100	50	80	10

Interruptions

During the tests, interruptions of up to 3 days before tests No. 1, 8, and 15 are allowed.

If there is an interruption before the test No 15, an identical brake application No 14 shall be carried out in addition outside the programme in order to observe the conditions for spaying water.

Temperatures

During the brake applications, care must always be taken to see that the starting temperature has fallen to the value given.

For the brake applications No. 1 and 8 a starting temperature between 20°C and 60°C is permissible.

Conditions for the spraying with water

The brake applications under wet conditions shall be carried out with a water quantity of 25 l/h for brake discs of 640 mm and 23 l/h for brake discs of 610 mm dia. During wet brake applications the spraying of the brake discs during the cooling intervals between the tests No. 14 and 35 shall not be interrupted.

After brake application No. 14, the spraying shall only begin when the brake disc temperature has reached 80°C.

Further conditions

- The brake applications shall be carried out in the given sequence.

- The number of bedding-in brake applications necessary for the contact pattern of at least 85% to be achieved (all leading edges of the rubbing elements) shall be given in the test report.

F.3 - Test programme No. 6C (v_{max} = 200 km/h, multiple unit trains with wheel brake discs)

reserved

Appendix G - Requirements for locomotive brake pads (v_{max} = 230 km/h)

Requirements for locomotive brake pads (v_{max} = 230 km/h) on the friction test bench

G.1:	Test programme No. 7A, Wheel brake discs	*reserved*
G.2:	Test programme No. 7B, Axle brake discs	*reserved*
G.3:	Instantaneous coefficient of friction μ_a	*reserved*
G.4:	Average coefficient of friction μ_m	*reserved*

Appendix H - Requirements for friction test benches

H.1 - Test methods and measurements to be carried out

H.1.1 - Grinding the brake discs

New or turned brake discs shall be ground outside the approval programme for brake pads and indeed with other brake pads than those which are to be used for the approval tests (however of the same type).

Depending on the test programme, a programme shall be carried out to grind the brake disc (see Table overleaf).

The situation before carrying out an approval programme for brake pads can be different as the four possibilities below show:

No. 1 The brake disc is new: the disc shall be ground as specified in the programme below.

No. 2 The brake disc has grooves or small cracks after the previous programme has been carried out.

The sides of the disc should then be turned flat as follows:

- all cracks must be removed, however one or two cracks with a length ≤ 25 mm are tolerated in each side of the disc;
- the following surface condition - measured with a roughness measuring instrument must be produced: $R_a \leq 1{,}5$ [μ_m] or $R_{z\ DIN} \leq 7$ [μ_m].

Then the grinding is done as specified in the programme below.

No. 3 The brake disc has no grooves but is certainly worn and the rubbing surfaces show traces of deposits of frictional material. Then the sides of the disc are cleaned, with the previous test pad by carrying out ten brake applications to a stand when wet, from 120 km/h with a total contact force of 10 kN, and a mass to be braked as specified in the following approval programme.

No. 4 The brake disc has already used, but has no cracks and no traces of frictional material deposits. It is thus already ground-in and so the approval programme can begin under the conditions of the test programme.

			Test programme	Grinding programme
Pad material	**Vehicles**	**Test programme v_{max}**	**See point**	**No. of the grinding programme**
Organic	High speed multiple unit trainset	1 (300 km/h) 3A (140 km/h)	B.1 C.4	RD 1 RD 2
	Passenger coach	2A (140 km/h) 2B (200 km/h) 3A (140 km/h) 3B (120 km/h)	C.1 C.2 C.4 C.5	RD 2 RD 2 RD 2 RD 2
	Wagon	4A (175 km/h) 4B (160 km/h)	D.1 D;2	RD 3 RD 3
Sintered	High speed multiple unit trainset	5 (320 km/h) 3A (140 km/h)	E.1 C.4	RD 4 RD 2
	Passenger coach	6A (200 km/h) 6B (140 km/h)	F.1 F.2	RD 2 RD 2
	Wagon	4A (175 km/h) 4B (160 km/h)	D.1 D.2	RD 3 RD 3

RD 1 : Use of the test series No. 1 to 11 of the programme No. 1 of Appendix B , point B.1 - page 17 with an initial temperature of maximum 80°C and without the brake applications at v_{max}.

RD 2 : Use of the test series No. 1 to 12 of the programme 2A (Appendix C , point C.1 - page 21) or programme 3B (Appendix C , point C.5 - page 29) or No. 1 to 18 of the programme 2B (Appendix C , point C.2 - page 23) or the programme 6A (Appendix F , point F.1 - page 39) or No. 1 to 14 of the programme 3A (Appendix C , point C.4 - page 27) or of the programme 6B (Appendix F , point F.2 - page 42) in accordance with the approval programme following the grinding of the disc. The brake applications can begin at a maximum initial temperature of 80°C, but the brake applications at v_{max} are not carried out (except for point C.5).

RD 3 : Use of the test series No. 1 to X (1st dry series) of the programme 4A (loaded wagons - Appendix D, point D.1 - page 32) or of the programme 4B (empty wagons - Appendix D, point D.2 - page 32) without the brake applications at v_{max} and with an initial temperature of 80°C.

RD 4 : Use of the test series No. 1 to 11 of the programme 5 of Appendix E, point E.1 - page 34 without the brake applications v_{max} and with a maximum initial temperature of 80°C.

The bedding-in brake applications (RD 1 to RD 4) shall be repeated as often as necessary until a $\Delta R_{Z\ DIN} < 2\ [\mu_m]$ ($\Delta R_a < 0{,}4\ [\mu_m]$) is obtained in two consecutive test series.

H.1.2 - Bedding-in the brake pads

The bedding-in of the brake pads is done as stated in the corresponding test programme.

H.1.3 - Test procedure for the approval programmes

The brake pads must be taken from series production, they must be in their original size and in new condition. They are bedded-in as specified in the test programme.

The brake applications of the test programme shall be carried out in the order specified, and may only be interrupted in the places stated in the test programme.

The arrangement of the brake callipers shall ensure, that the brake pads are centred against the rubbing surfaces of the brake disc (horizontal coaxiality between brake callipers and brake disc).

The increase of the contact pressure to 95% of the maximum value shall take place in $t_s = 4{,}0 \pm 0{,}2$ s measured from the increase in the pressure. The contact pressure F_b may only deviate during the brake applications to a stand by a maximum of $\pm$ 2% from the nominal value.

The brake should be released at the latest 5 seconds after the end of a brake application.

The test bench axle should be set in motion at the latest 1 minute after the end of the braking to a stand or braking on a gradient and accelerated to the required speed, unless the following braking is not carried out immediately from the same speed and no other stopping times are specified. The initial speed for the new brake application shall be set before reaching the initial temperature of the next brake application.

The following cooling conditions shall be observed:

	Test bench speed (km/h)		**Speed of the cooling air (km/h)**	
	dry	**wet**	**dry**	**wet**
During the brake application	< 200	v	v/2	10
	≥ 200	-	100	10
Between brake applications	100	50	80	10

The general fresh air plant to simulate the air flow over a moving coach shall work during the whole of the test as specified.

The water flow shall not be shut off during the wet tests. In order to avoid unnecessarily long cooling times between the wet tests, the water temperature should be between 10°C and 15°C.

During the test programme the behaviour of the brake should be observed and any unusual phenomena such as sparks, rings of fire, smoke, flames, burn marks, screeching, smells, etc. recorded.

Each test programme shall be done with new test samples. The pads shall be marked and kept for subsequent inspection. The pads and the two sides of the brake disc shall be photographed if there are deviations after the conclusion of the test programme. The photos shall be included in the test report.

New brake discs shall be ground-in outside the approval programme with other pads from the same manufactured batch. Depending on the test programme planned the grinding-in programme shall be done with the new brake disc (see Appendix H, point H.1.1 - page 46).

H.1.4 - Methods of temperature measurement

H.1.4.1 - Ventilated brake discs

The temperatures θ in °C shall be measured in at least 6 places 1 mm under the rubbing surface of the brake disc. A measuring point is located in the middle radius of the brake ring, the two others are displaced 120°, 40 mm outside or inside the middle radius.

H.1.4.2 - Unventilated brake discs

The temperature measurement shall be carried out by thermosliders, in which the radii correspond with the drilled thermoelements.

H.1.5 - Assessment of the brake tests

Besides recording and plotting the analogous measurement values, test reports shall be drawn up according to a standard model. The report shall give particulars of:

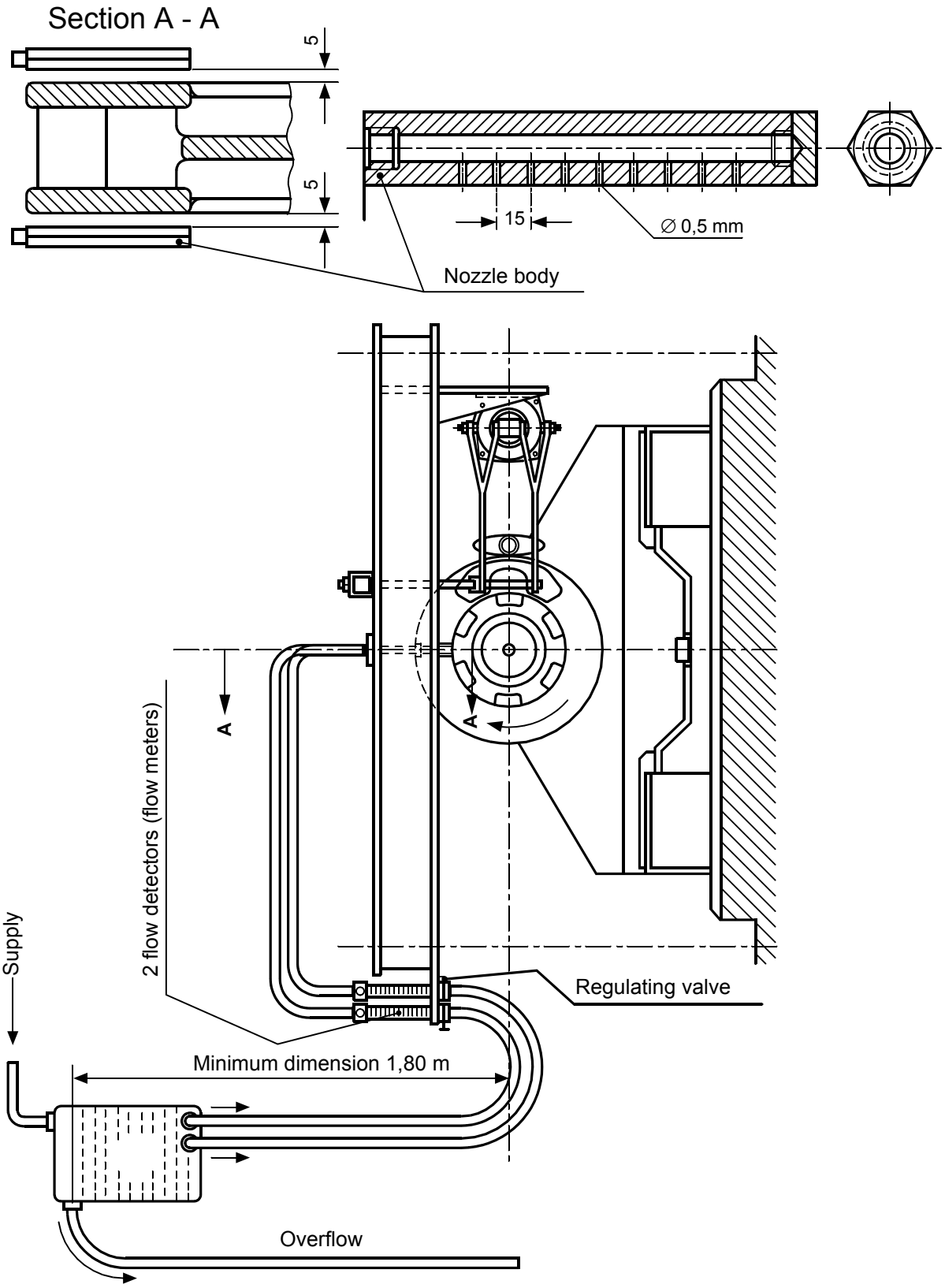
- the type of brake pads,
- the test programme,
- the test number,
- the volume and temperature of the water flow,
- the date and time of each brake application,
- the test speed and force applied by the brake pads,
- the ambient temperature and temperature of the air flow,
- any smell produced,
- any unusual occurrences when braking,
- the condition of the brake pads and the brake discs before and after the test programme.

The coefficient of friction μ_a shall be determined as the quotient F_t/F_b; other measured values are not acceptable.

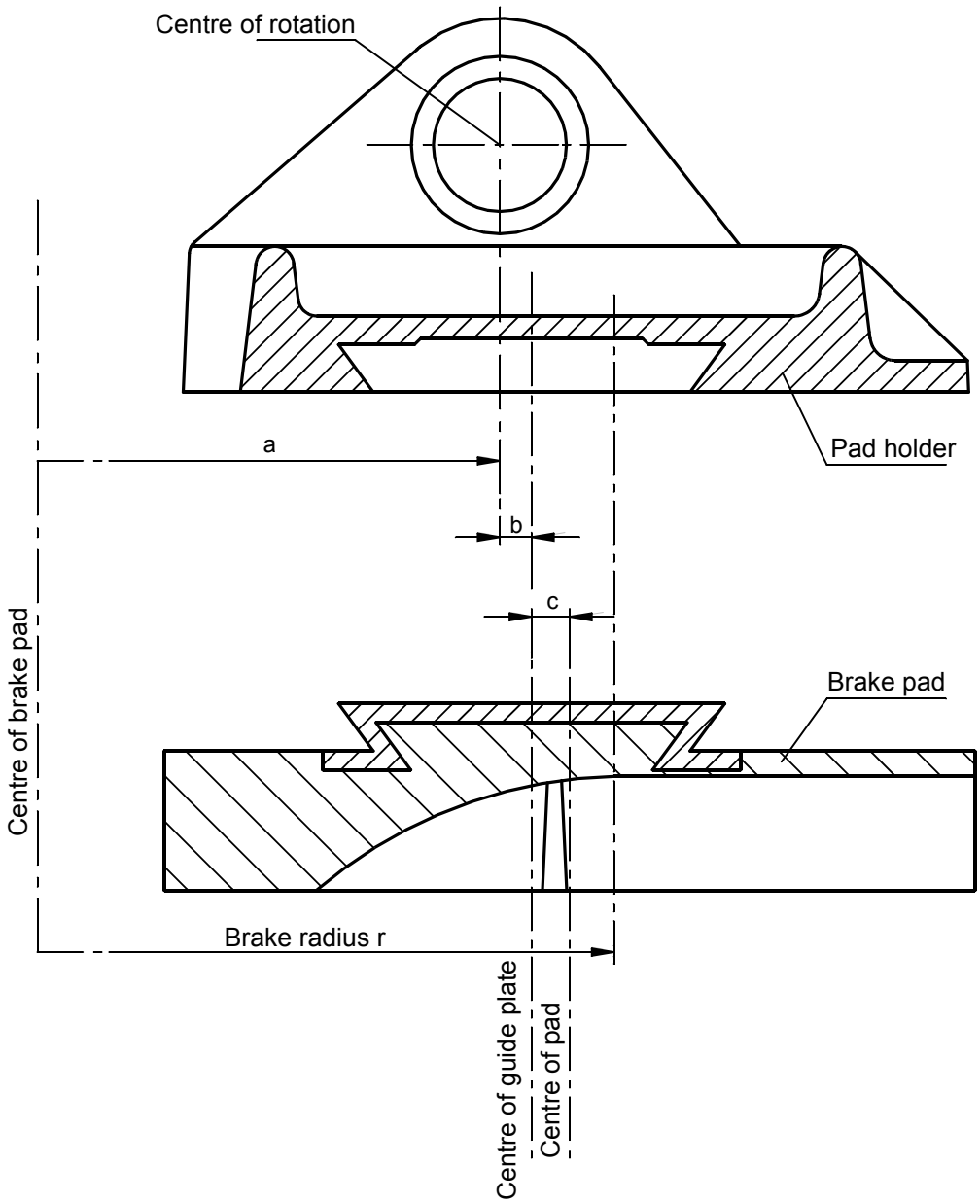
For each brake application (including the bedding-in brake applications) the following values should be worked out and included in the test report:

- initial speeds v_0 and v_2,
- braking distances s and s_2,
- average coefficient of friction μ_m,
- braking times t and t_2,
- average initial temperature and maximum temperature as well as the maximum average temperature,
- the wear of the pads by weighing.

H.2 - Test bench (wetting device)



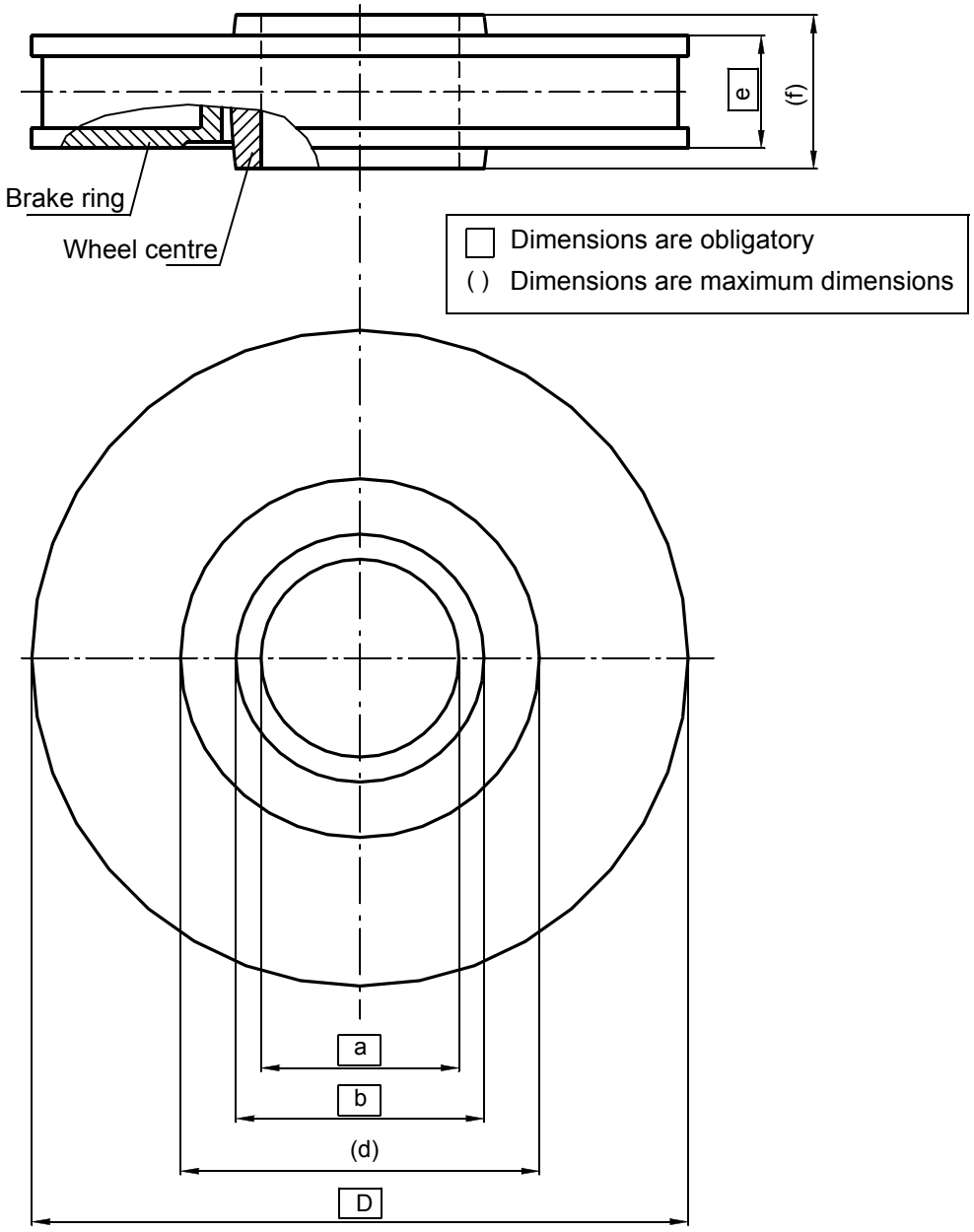
H.3 - Measuring point for brake pad force Fb/2



Organic and sintered materials					
S_{pad} [a] (cm^2)	Φ Disc (mm)	a (mm)	b (mm)	c [a] (mm)	r (mm)
200	640	230	6	5	247
200	610	215	6	5	233
175	610	213	0	6	233
175	590	210	0	6	230

a. s and c only apply for organic material.

H.4 - Axle brake disc with one piece rubbing ring



Dimensions of the axle brake disc					
D (mm)	d (mm)	e (mm)	a (mm)	b (mm)	f (mm)
640	max. 350	110 80 45	193 H6	232 - 242	max 150
610	max. 350	110 80 45	193 H6	232 - 242	max 150
590	315 - 330	110 80	193 H6	232 - 242	max 150

H.5 - Conditions for the international approval of friction test benches

H.5.1 - General

Friction test benches, on which approval tests for disc brake pads or composite brake blocks are to be carried out shall be internationally approved.

The approval of a friction test bench is granted by the SG5 and lasts for a period of 5 years.

The approval duration can be extended by periodical checks at 5 yearly intervals. If a periodic check is not carried out at the right time, the test bench loses its qualification and must be re-approved.

Test benches are divided into four categories A-D, which basically differ in the highest speed and the ability to simulate masses. The types of test programme for which they are suitable are laid down in these categories.

For the international approval and the periodical checking of a test bench **comparative calibration and checking tests** are necessary for which specific criteria are laid down in ***ERRI B 126 / RP 18*** (see Bibliography - page 61).

The comparative investigations shall be carried out on at least 2 test benches. If the values measured are different, if necessary, a third test bench should be used.

For the approval and periodic checking, each test bench operator shall specify a UIC RU which undertakes to formally monitor the procedure used. About a year before each approval and periodic check a corresponding application shall be submitted to the SG5.

For new approvals and periodic checks the following details shall be observed.

H.5.2 - New approval of a friction test bench

- The test bench operator shall apply through a supervising UIC RU to the SG5.
- The SG5 shall nominate a committee of experts and a comparative test bench.
- The costs shall be accepted by the test bench operator.
- The experts report shall be presented in German and French (25 copies each).
- The committee of experts shall prepare a recommendation for the SG5.
- The SG5 shall grant approval with entry in the Leaflet.

H.5.3 - Repeat check of a friction test bench

- The test bench operator shall apply through a UIC RU to the SG5.
- The test bench operator shall propose to the SG5 a committee of experts, whose members must not be involved in the preparation of the test bench report, and a comparative test bench.
- The test bench operator shall accept the costs for the comparison tests and the committee of experts.
- The Committee of experts shall present their report in German and French (25 copies each).
- The supervising UIC RU shall prepare a recommendation for the SG5.
- The SG5 shall decide on the extension of the approval with entry into the Leaflet.

H.5.4 - Special features

The SG5 should be immediately advised should modifications be made to the test bench or to the principles of the measuring chain and the SG5 shall decide what action should be taken.

In cases of doubt an immediate check should be carried out in the form of a periodic check. This is to establish the "maintenance of the accuracy by means of comparative calibration tests". It should be done by test benches that are already approved within the limits of their capability.

Modifications to the test bench without advising the SG5 shall cause the immediate loss of the international approval.

H.6 - Internationally approved friction test benches

The qualification of test benches to carrying out approval tests is granted by the SG5.

The test benches on which tests with brake pads may be carried out for approval in international traffic are divided into 4 categories depending on their ability to carry out different programmes. The Table below indicates which test programmes can be carried out by each test bench category.

Test bench category	Test programme
A	4A, 4B
B	2A, 2B, 3A, 3B, 4A, 4B, 6A, 6B
C	2A, 2B, 3A, 3B, 4A, 4B, 6A, 6B
D	1, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 6A, 6B

The list of the test benches suitable for carrying out approval tests may be found on the UIC-Internet pages (http://www.uic.asso.fr/Activities/Technology&Research/Products).

Appendix I - Brake pads approved for international traffic

The list of brake pads approved for international traffic may be found on the UIC-Internet pages (http://www.uic.asso.fr/Activities/Technology&Research/Products).

Appendix J - Terms used

In the data on the tolerance of the coefficient of friction a distinction must be made between:

- the instantaneous coefficient of friction μ_a, which is determined at any instant of the braking by the ratio of the total braking force F_t (at the rubbing radius r) to the total contact force F_b:

$$\mu_a = \frac{F_t}{F_b}$$

- the average coefficient of friction μ_m, which is determined by integrating the instantaneous coefficient of friction from reaching 95% of the nominal contact force F_B μ_a over the braking distance s_2:

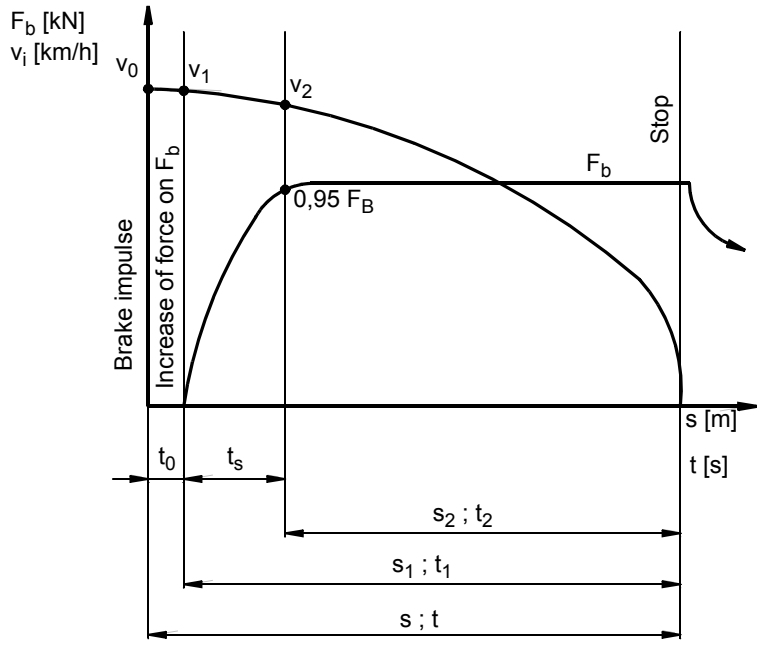
$$\mu_m = \frac{1}{s_2} \times \int_0^{s_2} \mu_a \times ds$$

Definitions and abbreviations

Disc brakes	
- Brake pad: rubbing element of a disc side	
- Pad half	
- Number of pad halves per brake disc:	N [-]
- Nominal surface area of a pad half (see note 1 - page 60):	S [cm^2]
- Theoretical brake radius of the brake disc:	r [m]
- Radius of the corresponding wheel	R [m]
- Specific pad pressure	$p = \frac{1000 \times F_B}{N \times S} [N/cm^2]$

Disc brakes and block brakes	
- The mass to be braked proportionally from a brake disc or a wheel (including the rotation component):	m [t]
- Total nominal contact force per disc or per wheel:	F_B [kN]
- Total instantaneous contact force per disc or per wheel:	F_b [kN]
- Average contact force (integrated over s_2):	F_{bm} [kN]
- Pressure in the brake cylinder:	p_c [bar]
- Instantaneous tangential force per brake based on the rubbing radius r (disc brakes):	F_t [kN]
- Instantaneous tangential force per brake based on the wheel radius (block brakes):	F_{tR} [kN]

-	Average tangential force (integrated over s_2): • based on the brake disc: • based on the wheel:	 F_{tm} [kN] F_{umR} [kN]
-	Total nominal brake load per disc for continuous brake applications (v and F_{tR} = const. controlled)	P [kW]
-	Average brake load (integrated over s_2):	P_m [kW]
-	Target speed at brake impulse:	v [km/h]
-	Instantaneous speed:	v_i [km/h]
-	Actual speed at brake impulse:	v_0 [km/h]
-	Correction factor of the speed:	K [-]
-	Speed at the beginning of the increase in force of F_b:	v_1 [km/h]
-	Speed at the time at which $F_b = 0{,}95 \times F_B$:	v_2 [km/h]
-	Dead time between brake impulse and the beginning of the increase in force of F_B:	t_0 [s]
-	Braking time of 0-95% of F_B :	t_s [s]



-	Total braking distance from the brake impulse until stopped:	s [m]
-	Total braking time:	t [s]
-	Braking distance from the start of the increase of force F_b until stopped:	s_1 [m]
-	Braking time corresponding to s_1:	t_1 [s]
-	Braking distance from the time when $F_b = 0{,}95 \times F_B$ until stopped:	s_2 [m]
-	Braking time corresponding to s_2:	t_2 [s]

-	Instantaneous deceleration:	$a\ [m/s^2]$
-	Average deceleration (calculated starting from v_0 and s):	$a_m = \frac{v_0^2}{2s}[m/s^2]$
-	Instantaneous coefficient of friction (brake pad):	$\mu_a = \frac{F_t}{F_b}$
-	Instantaneous coefficient of friction (brake block):	$\mu_a = \frac{F_{tR}}{F_b}$
-	Average coefficient of friction:	$\mu_m = \frac{1}{s_2} \times \int_0^{s_2} \mu_a \times ds$
-	Average initial temperature at the start of the brake application:	θ_0 [°C]
-	Maximum achieved temperature by the instantaneous average of the temperature:	θ_m [°C]
-	Instantaneous individual temperatures:	θ_i [°C]
-	Maximum individual temperature:	θ_{max} [°C]
-	Maximum temperature difference between 2 temperature measuring places of a disc side:	$\Delta\theta_{max}$ [°C]

Brake test benches		
-	Moment of inertia or flywheel (including test sample):	$I = 1000 \times m \times R^2\ [kg/m^2]$
-	Braking moment (moment of the brake force):	$M = 1000 \times r \times F_t$ [Nm]
	or	$M = 1000 \times R \times F_{tR}$ [Nm]
-	Frictional moment of the test bench corresponding to the speed v:	M_w [Nm]
-	Calculation factor of the average frictional moment of the test bench:	K_{Mw} [ ]
-	Instantaneous simulated mass to be braked (see note 2 - page 60) per wheel or per brake disc:	$m_{sim\ a}$ [t]
-	Average simulated mass to be braked (see note 2) per wheel or per brake disc:	$m_{sim\ m}$ [t]
-	Speed of the drive shaft:	n [tr/min]
-	Angular speed:	ω [rad/s]
-	Average coefficient of friction (see note 3 - page 60) per brake disc calculated from F_{bm} and s_2 (see note 4 - page 60): $\mu_{mF} = \left[\frac{v_2^2 \times m}{2 \times s_2} - \frac{K_{Mw} \times M_w}{R}\right] \times \frac{R}{r \times F_{bm}}$	(see note 5 - page 60)
-	Total quantity of water per brake disc or per wheel:	D [ℓ/h]

If the actual (real) flywheel mass (I_r) does not correspond to the flywheel mass (I) in the programme, the flywheel masses must be adjusted by a correction of the programmed brake initial speed v on the basis of the simulation of the same energy to the corrected speed v_k and indeed by:

$$v_k = K \times v \text{ with } K = \sqrt{\frac{I}{I_r}}$$

while meeting the following condition: $0,95 - K \leq 1,05$ (see note 6)

Notes :

1. In the case of sintered metal pads, this is the sum of the rubbing surfaces of a pad half.
2. For the tests with electronic flywheel simulation.
3. Without considering the units.
4. In the formula, m means:

   - $m_{sim\ m}$ for test benches with electronic flywheel simulation,
   - m_r for test benches with pure mechanical flywheel simulation.

   The calculation of $\left[\frac{0,7 \times M_w}{R}\right]$ is only necessary for test benches with mechanical flywheel simulation which do not have electronic compensation of the actual friction torque of the test bench.
5. The figures of K_{Mw} and M_w are given in the table in Appendix 3 of *ERRI B 126 / RP 18*.
6. At the time of publication of report *ERRI B 126 / RP 18*, there were some existing test benches where exceptionally a correction factor of K = 0,92 is permitted.

Bibliography

1. UIC leaflets

International Union of Railways (UIC)
UIC Leaflet 541-1: Brakes - Regulations concerning the design of brake components, 6th edition, November 2003

UIC Leaflet 541-4: Brakes - Brakes with composition brake blocks, 2nd edition of 1.10.90 and 3 Amendments (3rd edition in preparation)

UIC Leaflet 542: Brake parts - Interchangeability, 4th edition of 1.1.82 and 4 Amendments

UIC Leaflet 543: Brakes - Regulations governing the equipment of trailing stock, 13th edition, November 2006

UIC Leaflet 544-1: Brakes - Braking power, 4th edition, October 2004

UIC Leaflet 545: Brakes - Inscriptions, marks and signs, 7th edition, April 2002 (8th edition under preparation)

UIC Leaflet 546: Brakes - High power brakes for passenger trains, 5th edition of 1.1.67 - Reprint dated 1.1.80 incorporating 5 Amendments

UIC Leaflet 580: Inscriptions and markings, route indicators and number plates to be affixed to coaching stock used in international traffic, 6th edition of 1.1.90 and 3 Amendments

2. ERRI reports

International Union of Railways (UIC)
ERRI B 126 / RP 18: Braking problems - Dynamometers for international approval of friction materials, March 2000

ERRI B 126 / RP 26: Braking problems - Expert appraisal of SNCF's MF3 dynamometer, December 1997

ERRI B 126 / RP 27: Braking problems - Assessment of the PKP dynamometer, December 2000

ERRI B 126 / RP 28: Braking problems - Assessment of the ZSR dynamometer, October 2000

ERRI B 126 / DT 359: Braking problems - Periodic checking of the dynamometers on FS, CFR and CD, October 1998

3. International standards

International Organization for Standardization (ISO)
ISO 4287:1997 : Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters, 1997

Warning

Printed by the International Union of Railways (UIC)
16, rue Jean Rey 75015 Paris - France, November 2006
Dépôt Légal November 2006

ISBN 2-7461-1180-2 (French version)
ISBN 2-7461-1182-9 (German version)
ISBN 2-7461-1181-0 (English version)