



BSI Standards Publication

Railway applications — Braking — Definition of ETCS brake curve parameters for Gamma trains

National foreword

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European foreword

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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of an identical text or by endorsement, at the latest by July 2025, and conflicting national standards shall be withdrawn at the latest by July 2025.

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Introduction

European Train Control System (ETCS) specifications have become part of, or are referred to the Technical Specifications for Interoperability (TSI) for railway control-command systems, as part of the European legislation, managed by the European Union Agency for Railways (ERA).

The Braking model specification in this document is based on the definition in the System Requirements Specification (SRS) [SUBSET-026, Version 3.6.0 of 13/05/2016 \[11\]](#), published by the European Union Agency for Railways: [ETCS B3 R2 GSM-R B1 \[10\]](#).

Based on a generic “brake system architecture model” a procedure is described to design a train specific software model which is applied for calculating the rolling stock correction factors and a method for determination of the nominal emergency and service braking deceleration for normal and degraded modes is described. Furthermore, the derivation of all the required traction and braking model parameters is specified.

This document describes the different steps to define ETCS emergency and service brake parameters for ETCS gamma braking model trains intended to operate on lines equipped with ETCS Baseline 3 [10].

1 Scope

This document specifies the methodology to define the train related braking model and required emergency and service brake on-board parameters to enable speed and distance monitoring for trains equipped and operated on railway lines using ETCS Baseline 3.

This document is only applicable for ETCS Gamma braking model trains (i.e. the train is said to be a “gamma” train). This document does not specify the way these parameters are transferred to and can be used by the ETCS on-board system (e.g. during start of mission - SoM).

The ETCS “conversion models” are not covered by this document and are described in EN 16834:2019, Annex F. The ETCS “conversion models” are intended for use with trains where the braking performance is expressed using braked weight percentages (“lambda” train).

Any trackside related input parameters, including national values, are not covered in this document. Information can be found in the SUBSET-026 (see [11]).

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 15595:2018+A1:2023, *Railway applications — Braking — Wheel slide protection*

EN 16834:2019, *Railway applications - Braking - Brake performance*

EN 17343:2023, *Railway applications - General terms and definitions*

EN 50126-2, *Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 2: Systems Approach to Safety*

EN ISO 24478:2024, *Railway applications — Braking — General vocabulary (ISO 24478:2023)*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 17343:2023, EN ISO 24478:2024 and the following apply.

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

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

3.1.1

base unit

smallest considered unit of a certain system on the lowest level of the level model

3.1.2

building block

validated information for the characteristics of a brake sub-system (e.g. Magnetic Track Brake), that is derived from the difference between test results of configurations with and without the brake sub-system

3.1.3**highly improbable event**

event which is extremely unlikely to occur and can be neglected

Note 1 to entry: See also EN 50126-1:2017, Table C.1 [5].

3.1.4**brake system architecture model**

calculation model for some ETCS brake parameters which can be applied for K_{dry} definition with Monte Carlo simulation

3.1.5**level model**

model that enables the consideration of structural information of the vehicle in the brake system architecture model

3.1.6**technical function**

function, which can be generated by a single component or a complete system

Note 1 to entry: The technical function of the brake system is to generate braking force.

3.1.7**structural information**

information about the levels, units and structure used in a brake system

3.1.8**statistical information**

information that describes the failure or/and the deviation behaviour of a technical function

3.1.9**failure coefficient**

coefficient that represents the effect of the failure of a technical function on the braking force of a brake unit/group of brake units and is linked to the probability of failure of the technical function

3.1.10**deviation coefficient**

coefficient that represents the effect of the deviation of a technical function on the braking force of a brake unit/group of brake units and is linked to the statistical distribution of deviation of the technical function

3.1.11**normal mode**

operating condition with all expected brakes available and performing as specified

[SOURCE: ISO 24221:2024, 3.6]

3.1.12**degraded mode**

operating condition where some of the brakes are not available and/or not performing as specified (e.g. equipment failure, leakage)

[SOURCE: ISO 24221:2024, 3.7]

3.1.13

car

type of vehicle (e.g. trailer car, motor car)

Note 1 to entry: A trailer car can be a coach or a wagon, a motor car can be a locomotive.

3.2 Symbols and abbreviated terms

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

Table 1 — Symbols and abbreviated terms

Symbol	Definition	Unit
$A_{\text{brake safe}}(C,V,EBCL)$	safe emergency brake deceleration, also called $A_{\text{brake_safe}}$ in SUBSET-026-3 [11]	m/s ²
$A_{\text{brake safe dry}}(C,V,EBCL)$	safe emergency brake deceleration on dry rails	m/s ²
$A_{\text{nominal}}(C,V)$	nominal deceleration in emergency brake, also called $A_{\text{brake_emergency}}$ in SUBSET-026-3 [11]	m/s ²
$A_{\text{nominalSB}}(C,V)$	nominal deceleration in service brake, also called $A_{\text{brake_service}}$ in SUBSET 026-3 [11]	m/s ²
$A_{\text{normal}}(C,V)$	normal service brake deceleration, also called $A_{\text{brake_normal_service}}$ in SUBSET-026-3 [11]	m/s ²
C	identification of the configuration of the brakes (combination of special brake, degraded modes with brakes isolated, multiple unit operation, etc.)	—
F	braking force	N
$K_{\text{dry}}(C,V,EBCL)$	correction factor, also called $K_{\text{dry_rst}}$ in SUBSET-026-3 [11]	—
$K_i(C,V)$	correction factor for one random selected combination “i” (also called case “i”) of parameters (influencing braking force and failure behaviour) for calculation of deceleration	—
$K_n(V)$	speed dependent correction factors for gradient on the normal service brake; split in $K_{n+}(V)$ (uphill) and $K_{n-}(V)$ (downhill)	—
$K_{\text{wet}}(C,V)$	correction factor, also called $K_{\text{wet_rst}}$ in SUBSET-026-3 [11]	—
P	probability of failure	—
$t_{\text{eEB}}(C)$	equivalent emergency brake response time, also called $T_{\text{brake_emergency}}$ (for emergency brake) in SUBSET-026-3 [11]	s
$t_{\text{eSB}}(C)$	equivalent service brake response time, also called $T_{\text{brake_service}}$ (for service brake) in SUBSET-026-3 [11]	s
$t_{\text{tco}}(C)$	traction cut-off time, also called $T_{\text{traction_cut_off}}$ in SUBSET-026-3 [11], 3.13.2.2.2	s
V	identification of the speed interval	—
V_{max}	maximum design speed of the train	—
α	weighting factor representing the part of a brake unit/group of brake units/brake type force in the total braking force	—

Symbol	Definition	Unit
α'	ratio of the maximum force generated by a traction unit compared to the total braking force at train level	—
β	factor representing the product of the impact of all deviations and failure impacting the braking force of a brake unit	—
β'	factor representing the impact of possible traction cut-off failures leading to a reduction of total braking force by generation of a traction force	—
BCU	brake control unit	—
DBU	disc brake unit	—
EBCL	emergency brake confidence level	—
ECB	eddy current brake	—
ED	electro-dynamic brake	—
ETCS	European Train Control System	—
FIT	failures in time	—
MTB	magnetic track brake	—
Rnd	function providing a random value depending on a distribution type and on parameters	—
B	Bernoulli distribution	—
N	Normal distribution	—
U	Uniform distribution	—
TBU	tread brake unit	—
WSP	wheel slide protection	—

4 ETCS on-board brake model parameters

4.1 ETCS on-board emergency brake model parameters

4.1.1 Nominal emergency brake deceleration A_{nominal}

$A_{\text{nominal}}(C,V)$ is the established deceleration during an emergency braking for a given configuration of the train for a defined speed interval (see SUBSET-026-3 [11] and SUBSET-040 [12]). The determination of A_{nominal} is described in 7.2.

4.1.2 Correction factor $K_{\text{dry}}(C,V,EBCL)$

$K_{\text{dry}}(C,V,EBCL)$ is a rolling stock correction factor that, applied to A_{nominal} , gives the safe emergency brake deceleration for a given configuration of the train, on dry rails in accordance with the required confidence level, and for a defined speed interval (see SUBSET-026-3 [11] and SUBSET-040 [12]).

$$A_{\text{brake safe dry}}(C, V, EBCL) = K_{\text{dry}}(C, V, EBCL) \times A_{\text{nominal}}(C, V) \quad (1)$$

The determination of $K_{\text{dry}}(C,V,EBCL)$ is described in 7.3.

4.1.3 Correction factor $K_{\text{wet}}(C,V)$

$K_{\text{wet}}(C,V)$ is a rolling stock correction factor that considers in a limited way the loss of deceleration with regards to emergency braking on dry rails, when the emergency brake is applied on low adhesion rails, in accordance with wheel/rail adhesion reference conditions, and for a defined speed interval (see SUBSET-026-3 [11] and SUBSET-040 [12]).

$$A_{\text{brake safe}}(C, V, \text{EBCL}) = \left(K_{\text{wet}}(C, V) + M_{\text{NVAADH}} \times (1 - K_{\text{wet}}(C, V)) \right) \times A_{\text{brake safe dry}}(C, V, \text{EBCL}) \quad (2)$$

NOTE M_{NVAADH} is a trackside ETCS parameter and is not in the scope of this document.

The determination of $K_{\text{wet}}(C,V)$ is described in 7.4.

4.1.4 Emergency brake response time

The equivalent emergency brake response time t_{eEB} (see 7.5) is used to model the transition between the emergency brake demand and the fully established emergency braking force (see SUBSET-026-3 [11] and SUBSET-040 [12]).

4.1.5 Traction cut-off time

The traction cut-off time t_{tco} (see 7.6) is used to model the transition between the emergency brake demand or traction cut-off demand and the moment the acceleration due to traction (A_{traction}) is zero after a trainwide control signal for an emergency brake application.

4.2 ETCS on-board service brake model parameters

4.2.1 General

The service brake performance is not safety relevant. Therefore, no worst-case conditions (e.g. correction factors, adhesion conditions) are considered for its calculation.

4.2.2 Nominal service brake deceleration $A_{\text{nominalSB}}$

$A_{\text{nominalSB}}(C,V)$ is the established deceleration during a full service braking for a given configuration of the train for a defined speed interval (see SUBSET-026-3 [11]).

The determination of $A_{\text{nominalSB}}$ is described in 8.2.

4.2.3 Service brake response time

The equivalent service brake response time t_{eSB} (see 8.3) is used to model the transition between the full service brake demand and the fully established service brake braking force (see SUBSET-026-3 [11]).

4.2.4 Normal service brake deceleration and correction factors K_n

The normal service brake deceleration $A_{\text{normal}}(C,V)$ is used in combination with the speed dependent on-board correction factors for gradient $K_n+(V)$ and $K_n-(V)$ to calculate $A_{\text{normal_service}}(V,d)$. This deceleration is used to calculate the guidance curve (GUI), which is an optional braking curve in ETCS (see SUBSET-026-3 [11]).

Recommendations for determining A_{normal} are described in 8.4.

5 Brake system architecture model

5.1 General

The term “brake system architecture model” describes the model, which is applied when calculating the correction factor $K_{\text{dry}}(C,V,EBCL)$, and which is consistent with the determination of the nominal decelerations.

For this purpose, the brake system architecture model is a set of formulae and algorithms formed from parameters that influence braking performance.

The parameters consider both statistical and structural information related to braking.

The structural information depends on the specific vehicle architecture. The structural information shows how many brake units are affected when a specific parameter deviates or fails.

The statistical information contains both the probability and impact of a failure of a component (considering the structural information) and the behaviour of its deviation from the nominal values.

Both information elements are to be considered in the generation of the brake system architecture model.

The following clauses describe the steps to be followed for building a brake system architecture model representative of the real performance of the train, from a braking point of view.

The steps are organized to avoid missing any component in the brake system architecture model that can have an impact on the braking performance of the train.

The process is suitable for both new and existing vehicles or trains. Examples of the process are given in Annex C.

The technical scope of the model is determined by the components that are considered in the brake system architecture model. The intention is to consider all relevant impacts on the braking performance.

The definition of train related brake model includes all the parameters with influence on the braking performance. These parameters are not limited to the braking system, but can also come from other systems, such as power supply, vehicle control and the traction system.

Brake system components need energy to provide braking force. This energy is usually stored. There are pressure vessels or batteries for this purpose. Within the scope is the brake energy storage of the systems. Outside the scope are the systems that recharge the brake energy storage (e.g. compressors, generators).

The capacity of the brake system energy storage is usually dimensioned in such a way that minimum one braking application under any condition (environmental, load, speed, etc.) can be carried out without recharging. If this is not possible, the scope also refers to the systems for charging the brake system energy storages.

If a system operates without brake system energy storage, the systems for providing the energy are within the scope of this document.

Another consideration limit results from the maximum resolution that is achieved with the calculation model. The smallest unit is the so-called “base unit”. It leads to the maximum resolution of the model.

If relevant influences below the base unit are worked out within the framework of the technical analysis, these shall be considered in a suitable manner (see “model simplification” 5.2.4).

The brake system architecture model considers random failures and deviations of braking force relevant components. Systematically caused failures of technical functions or components are not considered. These are, among others, errors in construction documents or design documents.

Errors due to incorrect programming of software components are also included to systematically caused failures. These systematically caused errors shall be excluded by other suitable measures, such as design

reviews or quality controls. Systematically caused failure of software shall be managed in accordance with EN 50126-2.

5.2 General procedure description for $K_{dry}(C,V,EBCL)$ determination

5.2.1 General

The process is split in 3 steps as presented in Figure 1.

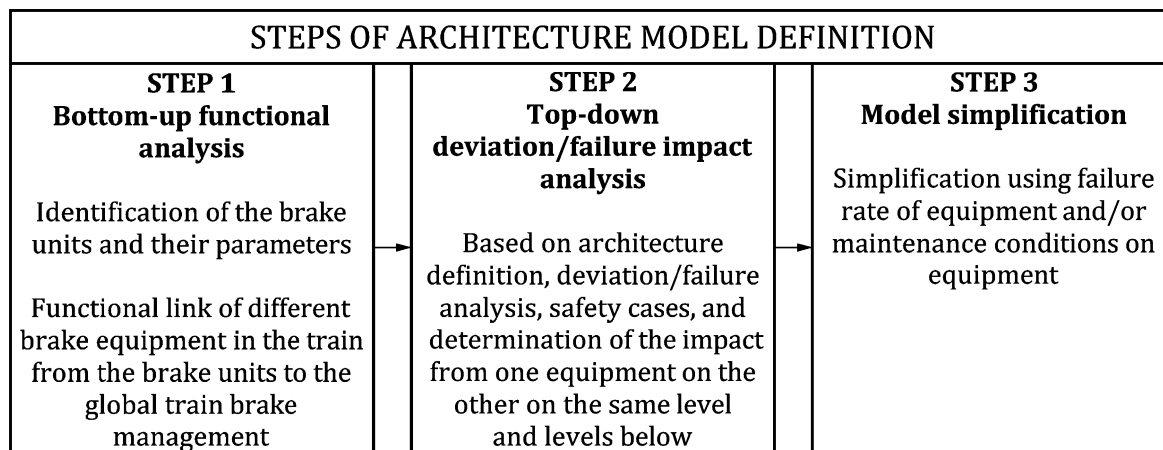


Figure 1 — General process description for the development of the brake system architecture model

In mandatory step 1, the functional analysis helps to define each brake component's position on the right level in the train and relations between them.

The mandatory step 2 based on impact analysis avoids missing any components which are not directly related to brake performance but can have an impact in case of failure or deviation.

The optional step 3 permits simplification of the brake system architecture model based on the behaviour of the components and the maintenance processes applied, to limit the mathematical model to the necessary extend to reduce computation time.

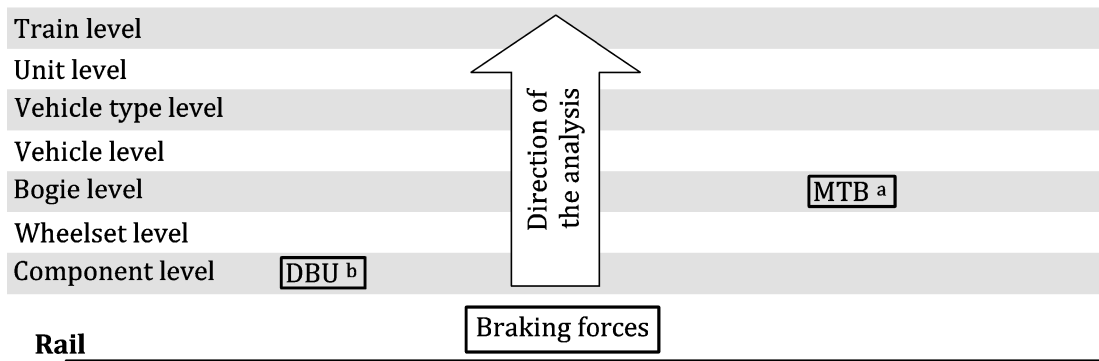
All the steps shall be documented to justify the representativeness of the model (see Clause 11).

5.2.2 Step 1: Bottom-up functional analysis

This step is based on the functional behaviour of the train. The aim is to represent all the brake components involved in emergency braking on the correct level in the train and draw functional links between them.

The process should start by identification of the sub-system generating braking forces (emergency brake units), their parameters and their location/level on the train (component level, bogie level, etc.).

Figure 2 gives an example of the first analysis.

**Key**

- a electric power supply/air supply/internal deviations and failures
- b coefficient of friction/efficiency/brake cylinder pressure/wheel diameter

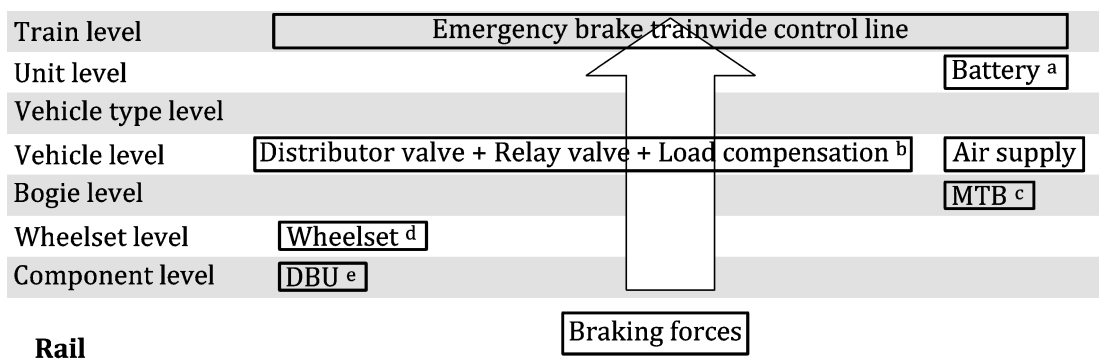
Figure 2 — Example of sub-systems generating braking forces located on right level of the train

For each brake unit identified, an analysis shall be performed to determine the different components positioned in upper levels of the structure that can have an impact of the braking force generated by the brake unit.

Special brakes as defined by SUBSET-040 [12] shall be identified at this step to allow the management of different configurations of brakes.

Once equipment and components are identified, the relevant characteristics which represent their behaviour shall be defined.

Figure 3 gives an example of the second analysis.

**Key**

- a electric power supply
- b brake cylinder pressure
- c internal deviations and failures
- d wheel diameter
- e coefficient of friction/efficiency

Figure 3 — Example of influencing component and relevant characteristics

This step can be performed using pneumatic and electric train diagrams and train brake functional descriptions.

5.2.3 Step 2: Top-down impact analysis

The aim of this step 2 is to identify other components (e.g. hardware, electronic control) that can have an impact on the emergency braking force in case of failure or of deviation.

NOTE Common cause failures of software are managed at software development phase and are not considered in this document.

These other components are possibly not directly involved in the braking force generation but can have an impact on train deceleration in case of failure or deviation (e.g. common battery for several magnetic track brakes).

By using a train safety case study and starting from the emergency brake trainwide control line down to the individual brake unit, it shall be possible to identify common modes for brake equipment groups and additional components, e.g. distributor valves or load compensation on vehicle level.

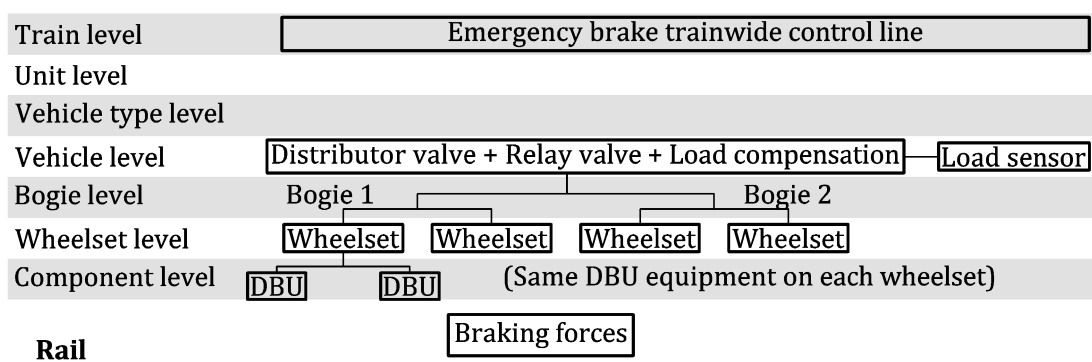


Figure 4 — Example of common points and additional components identified on a coach

As shown in the example in Figure 4, the top-down failure impact analysis has identified a common point with the distributor valve which manages two bogies. The failure and the parameters of this distributor valve impact all the DBUs of the two bogies.

The load sensor of the load compensation system has also been identified as a component having impact on the local brake control signal (pressure) sent to the disc brake units. Its failures and deviations impact the brake cylinder pressure, and so impact the braking force.

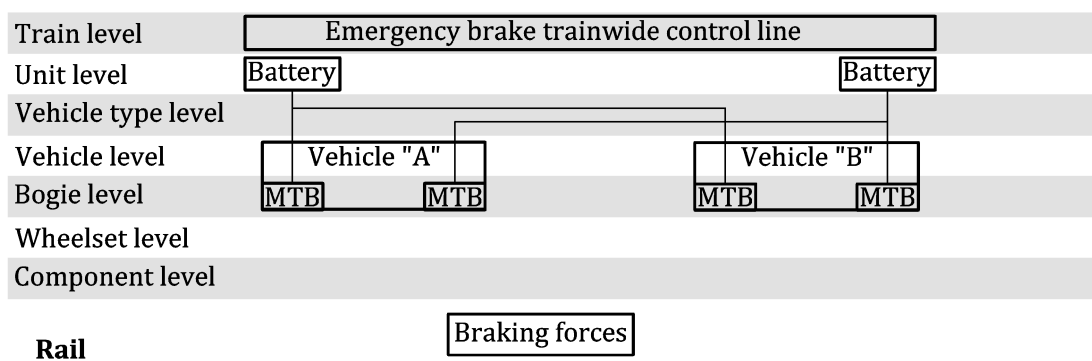


Figure 5 — Example of additional equipment having impact on magnetic track brakes

As shown in the example in Figure 5, the battery has been identified as a common point of the magnetic track brakes.

This step 2 also allows a double check after step 1 avoiding any missing case of brake behaviour.

5.2.4 Step 3: Model simplification

To reduce computation time and avoid unnecessary complex train modelling, possibility of simplifications can be studied. Simplifications shall not lead to a higher $K_{dry}(C,V,EBCL)$ value than with the step 2 model. These simplifications can only be made if valid justifications can be provided. Some simplifications are detailed in Annex E and examples in Annex C apply some of these simplifications.

Justification can be based on maintenance rules, safety case analysis or any study giving the proof of the similar behaviour of many components on the train.

Among others, the following simplifications are possible (this list does not claim to be exhaustive):

S-1 Grouping of components and technical functions

Grouping is a method of reducing the number of elements, by combining several components with equivalent statistical behaviour type (e.g. only uniform distributions, or only normal distributions) to form an assembly unit. This assembly unit is considered as one unit in the K_{dry} calculation.

S-2 “Worst case consideration”

The variation of the parameter can be simplified by using the worst-case constant value within the K_{dry} calculation. The considered “worst-case” constant value is the one on the probable range of the considered parameter which leads to the smallest total brake force.

S-3 Neglection of highly improbable event of failure (highly reliable technical function)

If the failure in a group of one or more identical components is identified as a highly improbable event, it is possible to neglect the failure probability of the group of components in the simulation.

To be considered as a “highly improbable event”, an event shall have a probability to occur less than or equal to 10^{-10} .

S-4 Reduction of model levels

By reducing the model levels, in combining the failure probabilities of the interrelated components on different architectural levels of the braking system into one failure probability.

This can be done by transferring the failure probability of the removed level to a higher level. The elements of the removed level should be combined in one failure probability and one deviation unit.

S-5 Assumption of permanently failed components

If the failure of a combination of n components among a group of m identical components is identified as a highly improbable event, then $(n-1)$ components can be considered as permanently failed and the failure probability of the $(m-n+1)$ remaining components is not considered.

S-6 Simplification for load compensated brake systems

For trains with load compensation devices, as the nominal deceleration is the lowest deceleration for the complete load range (in accordance with 4.4.1.2.4.2.1 in SUBSET-040,

[12]), the factor $\frac{m_{dyn,nom}}{m_{dyn}(i)}$ in Formula (3) can be considered as constant and equal to 1, and the

effect of load compensation is not considered in the calculation of the correction factor β .

NOTE In this simplification case S-6, $\beta_j(i, C, V)$ does not consider the direct impact of load compensation but can consider the possible deviation of load compensation device (e.g. tolerances).

5.3 Mathematical model building

The diagram obtained after step 2 or 3, if applicable, is used to create links between the basic formulae representing the behaviour of the different braking units (see Annex A for basic formulae).

The step 3 diagram shall be used to define which parameters of the braking units are driven by the same components on a higher train level to build a global train brake system architecture model which can be used for $K_{dry}(C,V,EBCL)$ calculation.

Results of dynamic tests performed on the train shall also be used to complete and validate the mathematical model with the proportion of contribution of each brake type to the global train braking force. For example, in Figure 4 one bogie is equipped with 4 DBUs which are linked to the same distributor valve. So, in the general formula, all the 4 DBUs will have the same brake cylinder pressure.

Those links shall be made for the complete train diagram obtained after step 3 to produce a mathematical model of the train brake system architecture model consistent with the $K_{dry}(C,V,EBCL)$ definition of the SUBSET-026 [11]: see Formula (1) and Formula (2).

For a case "i", on flat and dry track on a straight line with no consideration of the resistance against forward movement, the parameter $K_i(C,V)$ can be defined in accordance with Formula (3):

$$\begin{aligned}
 K_i(C,V) &= \frac{A(i,C,V)}{A_{nominal}(C,V)} \\
 &= \frac{F_{train, brake}(i,C,V)}{m_{dyn}(i)} \times \frac{m_{dyn,nom}}{F_{train, brake, nom}(C,V)} \\
 &= \frac{\sum_j [\alpha_j(C,V) \times \beta_j(i,C,V) \times F_{train, brake, nom}(C,V)] - \sum_k [\alpha'_k(C,V) \times \beta'_k(i,C,V) \times F_{train, brake, nom}(C,V)]}{\frac{F_{train, brake, nom}(C,V)}{\frac{m_{dyn}(i)}{m_{dyn,nom}}}} \\
 K_i(C,V) &= \frac{m_{dyn, nom}}{m_{dyn}(i)} \times \left[\sum_j [\alpha_j(C,V) \times \beta_j(i,C,V)] - \sum_k [\alpha'_k(C,V) \times \beta'_k(i,C,V)] \right] \quad (3)
 \end{aligned}$$

where

$A(i,C,V)$	is the train deceleration, for the case “i”, for brake configuration C, and for speed interval V, expressed in m/s^2 ;
$F_{\text{train,brake,nom}}(C,V)$	is the braking force at train level in nominal status, for the brake configuration C and the speed interval V, expressed in N;
$F_{\text{train,brake}}(i,C,V)$	is the braking force at train level in the case “i”, for the brake configuration C and the speed interval V, expressed in N;
$m_{\text{dyn,nom}}$	is the dynamic mass of the train in nominal configuration, expressed in kg;
$m_{\text{dyn}(i)}$	is the dynamic mass of the train for the case “i”, expressed in kg;
C	is the identification of the configuration of the brakes (combination of special brake, degraded modes with brakes isolated, multiple unit operation, etc.);
V	is the identification of the speed interval;
i	is the case corresponding to a random selected combination of parameters influencing braking force and failure behaviour;
j	is the identification of the brake unit(s) that covers all the brake units involved during an ETCS emergency braking;
k	is the identification of the traction unit(s) that covers all the traction units of the train;
$\alpha_j(C,V)$	is the weighting factor of the brake unit “j”, in nominal status, for the brake configuration C and the speed interval V; it is determined in 7.3.2;
$\beta_j(i,C,V)$	is the factor representing the product of the impact of all deviations and failure impacting the braking force of the brake unit “j” in case “i”, for the brake configuration C and the speed interval V; it is determined in 7.3.3;
$\alpha'_k(C,V)$	is the ratio of maximum force generated by the traction unit “k”, in nominal status (all traction units in service), for the brake configuration C and the speed interval V compared to the nominal braking force at train level in the same configuration $F_{\text{train,brake,nom}}(C,V)$; it is determined in 7.3.4;
$\beta'_k(i,C,V)$	is the factor representing the impact of possible traction cut-off failures leading to a reduction of the total train braking force by generation of a traction force by the traction unit “k” in status “i”, for the brake configuration C and the speed interval V; it is determined in 7.3.4.

NOTE 1 Dynamic mass is the sum of the static mass and the equivalent rotating mass, as set out in EN ISO 24478.

NOTE 2 By considering the maximum nominal traction force, it is not necessary to consider the deviations of parameters influencing traction force.

6 Input data

6.1 General

The mathematical model built from functional and failure analysis (Clause 5) highlights all the relevant brake units involved in the emergency braking such as disc brake unit, etc. It also identifies other components of the braking architecture of the train which have an influence on basic brake unit behaviour.

Each brake unit can be modelled by its relevant parameters (see Annex A for common brake unit parameters) considering also general data from train level.

All those parameters, which are considered in the mathematical model, are input data for the $K_{dry}(C,V,EBCL)$ calculation.

To be used through the Monte Carlo method, all input data shall be defined in a statistical way.

The statistical description of the input data is dependant of its impact and behaviour on the train.

Depending on this impact, a distribution type shall be selected.

The Table 2 gives the description of the common distribution types and in which case they can be used. Any other statistical distribution may be used if justified by data.

Table 2 — Examples of possible statistic behaviour

Distribution type	Input parameter	Applicable for
Bernoulli	Failure probability	Technical functions
Normal	Mean and standard deviation value	Physical parameters with a distribution maximum without limits
Normal with limits	Mean, standard deviation, maximum and minimum value	Physical parameters with a distribution maximum with limits
Uniform	Maximum and minimum value	Physical parameters with uniform distribution between the limits
Beta distribution	Alpha and Beta	Physical parameters with a continuous (symmetrical and asymmetrical) distribution with limits

6.2 Origin of input data

Depending on the project type (new train or already operational train to be equipped with ETCS), the information used to define the statistical description of each input data can be provided by the component supplier, the vehicle builder or the railway undertaking. The statistical information on the frequency of component failures needs to be considered as shown in 7.3.3 and Annex F.

The origin of information for each input data shall be noted to justify the representativeness of the input definition regarding the train behaviour.

In any case, the method used for statistical input definition shall consider maintenance tolerances and the maintenance plan applied.

The statistical distributions used for the simulation shall be defined to describe the physically correct variance around the nominal conditions.

6.3 Validity of input data

The input data used for the determination of the ETCS emergency brake parameters is principally valid as long as the train characteristics and the relevant maintenance procedures do not change.

During the lifetime of the rolling stock, the maintenance shall be adapted or the ETCS on-board parameters shall be recalculated if the input parameters are outside of the range (nominal value and tolerance/distribution/failure rate or probability) that has been used when determining the brake parameters (nominal deceleration A_{nominal} , equivalent response time t_e , $K_{\text{dry}}(C,V,EBCL)$ and $K_{\text{wet}}(C,V)$).

NOTE 1 The failure probability of equipment/function is closely linked to operational brake test strategy and frequency, but this is not part of this document.

The train characteristics which are relevant are:

- nominal deceleration A_{nominal} and equivalent response time t_e .

The nominal deceleration A_{nominal} and equivalent response time t_e can change if for example mass changes (due to changes/modernization) or brake forces change (friction material changes, brake cylinder pressures changes) or the brake control equipment changes (other trainwide brake control device, control valves, piping lay-out, volume of brake reservoirs).

NOTE 2 This is not an exhaustive list; more aspects can influence the nominal deceleration A_{nominal} or equivalent response time t_e .

- rolling stock correction factors $K_{\text{dry}}(C,V,EBCL)$ and $K_{\text{wet}}(C,V)$.

$K_{\text{dry}}(C,V,EBCL)$ can change if other equipment is used or maintenance rules changes.

$K_{\text{wet}}(C,V)$ can change if WSP device (in accordance with current definition in SUBSET-040) or settings changes (e.g. filling/venting times, max. deceleration).

Influences on these characteristics require a check and possibly a re-assessment of the relevant brake parameters.

7 Determination of ETCS emergency brake model parameters

7.1 Parameters

7.1.1 General

The brake performance and characterization against speed for trains at specific configurations, when applying the emergency brake (when activated by an ETCS emergency brake demand), are expressed using the “nominal emergency brake deceleration” ($A_{\text{nominal}}(C,V)$). This nominal characterization value is valid for the nominal situation, which is the theoretical condition where there are no deviations that are influencing the characterization.

This is theoretical, since there are always deviations present or at least possible, resulting in a non-nominal behaviour. For ETCS, to be a safe system (against safety requirements) therefore not the nominal deceleration is used, but the “safe emergency brake deceleration” ($A_{\text{brake safe dry}}(C,V,EBCL)$). This safe brake deceleration is determined by applying the rolling stock correction factor $K_{\text{dry}}(C,V,EBCL)$ corresponding to the confidence level of the safe emergency brake deceleration, as required by the trackside (national value emergency brake confidence level (EBCL)) to the nominal deceleration. This is an application of Formula (1) when emergency brake is applied on dry rails (without considering $K_{\text{wet}}(C,V)$):

$$A_{\text{brake safe dry}}(C,V,EBCL) = K_{\text{dry}}(C,V,EBCL) \times A_{\text{nominal}}(C,V)$$

To determine the safe emergency brake deceleration for degraded modes there are in general 2 common methods used, that differ in their approach from a historical country/institution/company specific background. In the end it is not relevant which approach is followed. Although the nominal deceleration value and $K_{\text{dry}}(C,V,EBCL)$ correction factor are handled differently, the result is the same characterization of safe emergency brake deceleration. Therefore, both approach options are allowed for the general definition of the ETCS brake parameters. They produce the same result despite using two different determination paths (see Figure 6). For further details of the approaches, see 7.1.2.

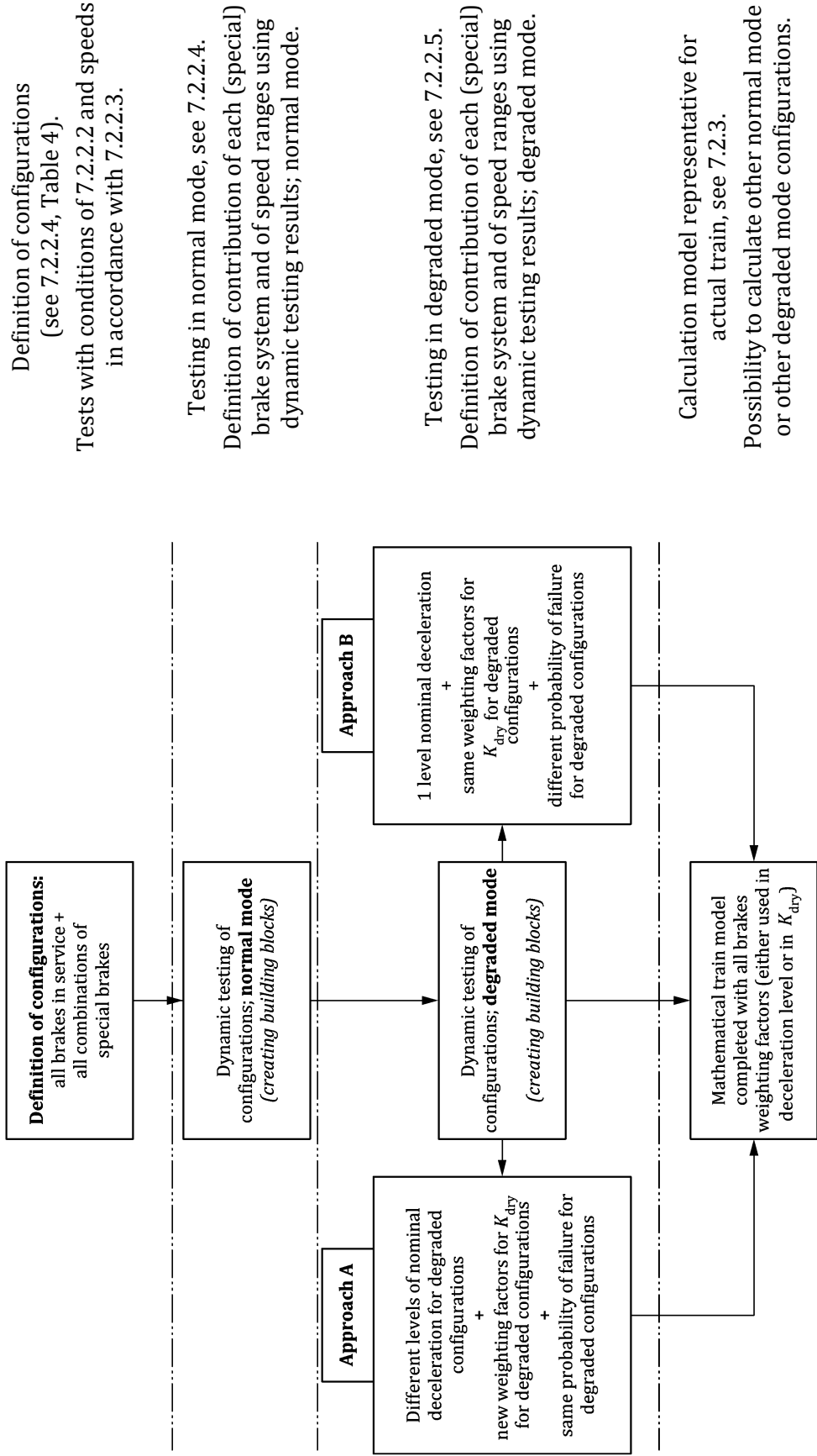


Figure 6 — Steps and related subclauses to determine validated deceleration values (by tests and/or calculation)

7.1.2 to 7.1.4 give details about the process to be followed to determine all the ETCS brake parameters. The general process is the same for the two options. Only the number of parameters and their values can be different for defined train configurations.

7.1.2 ETCS brake parameters set approaches

Approach A and B are the same for normal mode but differ in the way the effect of the degraded mode on the nominal deceleration and the $K_{dry}(C,V,EBCL)$ determination is considered. There is no distinction made in the determination of $K_{wet}(C,V)$, emergency brake response time t_e or traction cut off time t_{tco} .

Approach A: determines the safe emergency brake deceleration by applying the effect of the degraded mode, e.g. one pneumatic bogie isolated, to determine the effect on the value of the nominal deceleration (use of multiple nominal deceleration values). The nominal deceleration value for normal mode is reduced to a lower nominal deceleration value (in comparison to normal mode), for the specific configurations of the degraded modes. This is combined with the $K_{dry}(C,V,EBCL)$ determination using only the elements of the same degraded mode configuration, e.g. with one pneumatic bogie isolated. So, for this configuration no more input concerning the isolated bogie is used in the $K_{dry}(C,V,EBCL)$ determination. The same method applies for other degraded modes. Brake units that are isolated, are no longer considered as elements in the $K_{dry}(C,V,EBCL)$ determination. This results in new weighting factors (for the $K_{dry}(C,V,EBCL)$ determination) for the remaining operational brake units.

Approach B: determines the safe emergency brake deceleration by using an unchanged nominal deceleration (of the normal mode) and determines the effect of the degraded mode by adapting only failure probability inputs of the $K_{dry}(C,V,EBCL)$ correction factor (e.g. with one pneumatic bogie isolated as an input).

Summarized, when determining the effects of degraded modes, the results of the same dynamic test configurations will be used differently, depending on the chosen approach (see Table 3):

- Approach A uses dynamic braking test results to determine different levels of nominal deceleration characterization, for each degraded mode. Degraded brake elements are no longer part of the $K_{dry}(C,V,EBCL)$ calculation, e.g. by either deleting them from the $K_{dry}(C,V,EBCL)$ calculation or setting the shares on the total braking force for the isolated brake elements equal to 0.
- Approach B keeps the nominal deceleration (of the normal mode) unchanged. Instead, it uses dynamic braking test results to determine weighting factors in the $K_{dry}(C,V,EBCL)$ determination with all brake elements being part of the $K_{dry}(C,V,EBCL)$ calculation. The probability of failure for degraded brake elements is set equal to 1 (100 %).

A further detailing of the effect of the 2 approaches in the $K_{dry}(C,V,EBCL)$ determination can be found in 7.1.3. Table 3 illustrates how approaches A and B handle the specific degraded modes differently.

Table 3 — Approaches A and B regarding determination of safe deceleration components for normal and degraded modes (for 1 to n different combinations of special brakes)

Active brakes	Approach A		Approach B	
	Normal mode	Degraded mode ^a	Normal mode	Degraded mode ^a
All special brakes active	A_{nominal}	$A_{\text{nominal_degraded}}$ $(= (1- \alpha_{\text{tot isolated}}) \times A_{\text{nominal}})$	A_{nominal}	
	K_{dry}	$K_{\text{dry_degraded_A}}$	K_{dry}	$K_{\text{dry_degraded_B}}$ $(= (1- \alpha_{\text{tot isolated}}) \times K_{\text{dry_degraded_A}})$
	K_{wet}		K_{wet}	
	t_{eEB}		t_{eEB}	
	t_{tco}		t_{tco}	
Specific combinations of special brakes active (#1 to #n)	$A_{\text{nominal},1..n}$	$A_{\text{nominal_degraded},1..n}$ $= (1- \alpha_{\text{tot isolated}}) \times A_{\text{nominal},1..n}$	$A_{\text{nominal},1..n}$	
	$K_{\text{dry},1..n}$	$K_{\text{dry_degraded_A},1..n}$	$K_{\text{dry},1..n}$	$K_{\text{dry_degraded_B},1..n}$ $(= (1- \alpha_{\text{tot isolated}}) \times K_{\text{dry_degraded_A},1..n})$
	K_{wet} or $K_{\text{wet}, 1..n}$		K_{wet} or $K_{\text{wet}, 1..n}$	
	t_{eEB} or $t_{\text{eEB}, 1..n}$		t_{eEB} or $t_{\text{eEB}, 1..n}$	
	t_{tco}		t_{tco}	
^a Component(s) isolated at start of mission. $\alpha_{\text{tot isolated}}$ = sum of weighting factors of the component(s) isolated at start of mission.				

7.1.3 Approach dependency of ETCS brake parameters set

The results of the dynamic brake testing of the normal mode and the degraded mode are compared to determine the absolute contribution of each braking system on the total braking force and to define weighting factors for the specific brake types for normal mode, see Formula (4).

$$\alpha_{\text{specific brake type}} = \frac{\text{Total nominal braking force of the specific brake}}{\text{Total nominal braking force for normal mode}} \quad (4)$$

This is determined from the change of brake force contribution when specific degraded modes are valid. These weighting factors can be used to validate if the assumed weighting factors of the specific brake type are correct or need to be adjusted.

α has a configuration and speed dependency ($\alpha(C,V)$). It shall be given as a step function of speed, with the same speed intervals as used for $A_{\text{nominal}}(C,V)$.

At **Approach A**: $\alpha_{\text{specific brake type}}$ values are used to determine the nominal decelerations for degraded modes (component(s) isolated at start of mission are represented with sum of weighting factors: $\alpha_{\text{tot isolated}} = \sum \alpha(\text{specific brake type isolated})$). The calculation is shown in Formula (5).

$$A_{\text{nominal degraded}} = (1 - \alpha_{\text{tot isolated}}) \times A_{\text{nominal}} \quad (5)$$

The resulting weighting factors which are needed for the simulation are shown in Formula (6) (with the share of the specific brake in the total braking force being 0 for isolated brakes).

$$\alpha_{\text{specific brake type, degraded mode}} = \frac{\text{total nominal braking force of the specific brake}}{(1 - \alpha_{\text{tot isolated}}) \times \text{total nominal braking force for normal mode}} \quad (6)$$

$P_{\text{specific brake type}}$ is for the degraded mode always equal to $P_{\text{specific brake type}}$ for the normal mode.

At Approach B: the nominal deceleration for degraded mode and normal mode are kept the same. The $\alpha_{\text{specific brake type}}$ values are here set together with the probability of failure ($P_{\text{specific brake type}}$). The calculation is shown in Formula (7).

$$A_{\text{nominal degraded}} = A_{\text{nominal}} \quad (7)$$

$$\alpha_{\text{specific brake type, degraded mode}} = \alpha_{\text{specific brake type}}$$

and

$$P_{\text{specific brake type, degraded mode}} = P_{\text{specific brake type, normal mode}}$$

where

$$P_{\text{specific brake type, normal mode}} \text{ is "1" for isolated brakes.}$$

7.1.4 Resolution of ETCS brake parameters

ETCS Brake parameters include $A_{\text{nominal}}(C,V)$, $K_{\text{dry}}(C,V,EBCL)$ and $K_{\text{wet}}(C,V)$ values. Those data shall be defined for all train operational configurations. The values for $K_{\text{dry}}(C,V,EBCL)$ and $K_{\text{wet}}(C,V)$ shall be rounded to 0,01, and for A_{nominal} to 0,01 m/s². The values for t_e and t_{tco} shall be rounded to 0,1 s. The values are rounded in accordance with mathematical rules.

7.2 Nominal emergency brake deceleration

7.2.1 General

The determination of A_{nominal} shall be carried out in accordance with EN 16834:2019. Dynamic brake testing is performed, to gather input data to determine the values for parameter sets with a maximum of 7 speed intervals covering the complete speed range. Next to the nominal deceleration profile (a_{bi} in EN 16834), the parameter set also contains values for the equivalent response time t_e (see 7.5). These data are determined for each brake configuration C.

In general, a system of building blocks of data for specific configurations, that is validated by dynamic tests, is used to build brake calculations for other configurations. Since the brake calculation is built on validated building blocks, also the resulting configuration can then be considered as (indirectly) validated. For both normal mode and degraded modes, the method for creating validated building blocks and derived brake calculations is given.

7.2.2 to 7.2.5 give the overall structure of the determination methods, with general descriptions and referrals to specific content of EN 16834:2019 that is applicable for this method; with supplemental information and requirements to EN 16834:2019, only when needed.

For cost efficiency, the multitude of dynamic brake testing needed for the determination of the nominal deceleration needs to be minimized. This is achieved by using a method where tests are only to be performed for specific combinations of brake control/type systems. These combinations are chosen in such a way that they result in validated information for each of the used brake control/type systems. This information can be considered as validated “building blocks” for each system which can be subsequently used in brake calculations, to determine the nominal deceleration for untested combinations brake control/type systems. Since the building blocks are validated, also the brake calculations built from these blocks are considered as validated.

In 7.2.2 and 7.2.3 this method is further detailed, including the determination of the nominal deceleration for normal and degraded mode.

7.2.2 Determination by dynamic brake testing

7.2.2.1 General

Determination of A_{nominal} by dynamic brake testing shall be performed in accordance with EN 16834:2019, Clause 7. In 7.2.2.4 the combinations of brake control/type systems to be tested are given for normal mode. In 7.2.2.5 this is given for degraded mode.

7.2.2.2 Conditions for dynamic brake testing

The conditions for the determination of the nominal emergency brake deceleration profile are set by SUBSET-040 [12]. Environmental and nominal conditions compliant with SUBSET-040 are defined in EN 16834:2019, 6.4 and 6.6.

7.2.2.3 Test speeds

Braking from maximum initial speeds does not always lead to the lowest deceleration compared to braking from lower initial braking speeds (see EN 16834:2019, 7.3.2.1), e.g. depending on the behaviour of friction components against initial braking speeds. Consequently, more initial speeds should be used for dynamic brake testing than just the maximum design speed.

At least four (4) emergency braking tests results shall be used for each initial speed.

Initial test speeds shall be speeds up to maximum train design speed with steps lower or equal to 40 km/h. Initial test speeds should include the maximum train design speed + overspeed to consider the tolerance on speed for ETCS EBI curve (overspeed is defined in SUBSET-026-3 [11], 3.13.9.2.3) otherwise a coefficient ≤ 1 based on frictions' behaviour in accordance with SUBSET-026-3 [11] (from test bench result or from extrapolation of dynamic tests) shall be applied on $A_{\text{nominal}}(C,V)$ for the speed interval which covers this overspeed. If there is significant change in brake deceleration at specific speeds due to brake system architecture (e.g. minimal speed of MTB application, high/low pressure transition in brake cylinder), then tests for these specific speeds shall be done.

NOTE Commission Regulation (EU) No 1302/2014 [9], EN 16185-1 [4], EN 15734-1 [3] and EN 16834 provide some test speeds covering this requirement.

If in certain speed intervals the nominal deceleration values a_{bi} calculated based on the initial braking speed (which differs from v_{max}) are lower than those determined using v_{max} , then the lowest deceleration values a_{bi} shall be used.

7.2.2.4 Normal mode

The determination of nominal deceleration by means of dynamic brake testing is the same for both approaches A and B since normal mode testing is applicable for both approaches.

Table 4 gives the minimal combinations of brake control/type applications that shall be tested (by means of dynamic brake test carried out at the speeds of 7.2.2.3). The combinations in Table 4 are required to be able to automatically switch in parameter values (or parameter sets) in case of change of either a track condition profile (prohibiting or allowing the use specific special brake systems) or a specific brake status (active/not active).

For other combinations either additional dynamic brake tests or brake calculations (which conform to EN 14531-1:2015+A1:2018 [1] or EN 14531-2:2015 [2]) are allowed as input to determine either values of deceleration (A_{nominal} , see 7.2) and/or equivalent response time (t_e , see 7.5) for specific brake control/type combinations. See 7.2.3 in case brake calculations are used.

Table 4 — Minimum combinations of brake type/ active brake control for dynamic brake tests - normal mode

Test		Brake control/type system active			
		Main brake system	Special brake system ^a		
		For all available brake positions and brake systems excluding special brakes (via pneumatic ^b or direct electro-pneumatic (EP) brake control ^c)	Regenerative brake ^d	Magnetic track brake	Eddy current brake
Condition for dynamic brake tests	Emergency braking	X			
	Emergency braking, only when ED brake is activated	X	X ^e		
	Emergency braking, only when MTB is present and allowed to be activated	X	X ^e	X	
	Emergency braking, only when eddy current brake is present and allowed to be activated	X	X ^e		X
^a Special brake systems as defined in SUBSET-026-3 [11]. ^b When an EP-assist system is present, the main brake dynamic tests results are with this system active (availability/failure of the EP-assist system is in this case part of the $K_{\text{dry}}(C,V,EBCL)$ determination). ^c In case the brake pipe function is replaced by an electrical direct control system. ^d An ED-brake can be a rheostatic or regenerative brake. Only the regenerative brake is an ETCS special brake (dependant on track conditions). Both types need however to be tested, in case the ED brake is activated. ^e Only when regenerative brake is activated at emergency brake application.					

7.2.2.5 Degraded mode

Dynamic brake testing in the degraded mode is performed equally for approaches A and B.

For degraded mode testing the same principle as described for normal mode is applicable. Dynamic brake tests with 1 part (bogies, wheelsets, etc.) isolated, combined with results from the dynamic brake tests of the normal mode (as described in 7.2.2.4), is used to determine validated information for the tested degraded modes (by comparison of results of normal mode against degraded mode for tested configurations).

The lowest element to be isolated is at bogie level. More detailed information for base unit parts (which can be isolated independently) at lower levels than the bogie level (e.g. wheelsets, etc.) shall be derived from the information at bogie level, depending on their share at bogie level (e.g. for 2 wheelsets with 50/50 share at bogie level, each wheelset contribution is 50 % of the bogie contribution).

Repeating this for all brake systems, for which degraded modes are possible in accordance with Table 5, results in validated information for all degraded modes with 1 brake part degraded. This validated information is used for calculations of other degraded mode configurations (see 7.2.4).

When brake units depend on a power supply, the information of isolation of all brake units does not need to be tested. This information is already derived by the relative testing in normal mode, as described in 7.2.2.4.

Table 5 — Minimum combinations of brake type/ active brake control for dynamic brake tests – degraded modes

Test		Brake control/type active				
		Main brake; 1 bogie isolated ^{a, b}	Main brake; optional other degraded mode ^{b, c}	Electro-dynamic brake 1 motor bogie isolated ^b	Magnetic track brake; 1 bogie isolated ^b	Eddy current brake; 1 bogie isolated ^b
Combination for dynamic brake tests	Emergency braking ^b	X	X			
	Emergency braking ^b , only when ED brake is activated			X		
	Emergency braking ^b , only when MTB is present				X	
	Emergency braking ^b , only when eddy current brake is present					X
^a The bogie with the highest contribution to the brake performance is to be isolated. When isolation is not possible at the bogie level, the next higher level can be used instead (e.g. vehicle level). If advantageous, this combination can be tested for both a trailer and a motor bogie. ^b All brake systems that are activated are operational. ^c It can be decided if certain other degraded modes have an unacceptable probabilistic occurrence rate, e.g. failure of air suspension device and/or load-proportional valves. In that case these degraded modes are recommended to be tested as well. When occurrence rates of these modes are acceptably low, a worst-case brake calculation (instead of testing) can suffice.						

NOTE For specific architectures (e.g. vehicle without bogie), the program of test can be adapted.

7.2.2.6 Criteria to accept tests

To accept tests for the determination of nominal deceleration in principle the same criteria K1 and K2 shall be applied, which are defined in EN 16834:2019 for stopping distances.

EN 16834:2019, 6.7.1 and 6.7.2 shall be applied for all tests with nominal initial speeds of 60 km/h or higher. For lower initial speeds the application of EN 16834:2019, 6.7.2 is not required; the mean stopping distance can be determined based on all relevant test results and no specific criteria (K1 and K2) for determining the mean stopping distance need to be applied.

If one or more pneumatic friction brake unit pressure on the test vehicle deviates from its nominal value more than $\pm 0,2$ bar (value from EN 16834:2019, which is equivalent to about ± 5 % for UIC brake systems) then the test shall not be accepted. For other brake unit's type, their performance and/or parameters should not deviate from their nominal value of more than ± 5 %.

7.2.2.7 Correction dedicated to deceleration tests

Decelerations obtained in test shall be corrected to consider – if necessary – the gradient and curve resistance of the test track.

The correction shall be done, if

- accelerations are **not** measured by an accelerometer, which compensates the influence of gradients during the measurement,
- tests were performed in curves of between 1 000 m and 5 000 m radius (above 5 000 m radius, the curve resistance is negligible).

The correction shall be done for each a_{jk} in accordance with EN 16834:2019, 7.3.2.2 b) using Formula (8).

$$a_{jk,corr} = a_{jk,meas} - \frac{g}{\rho} \times \frac{i'_m}{1000} \quad (8)$$

with

$$i'_m = i_m + W_{Bo} \quad (9)$$

where

- $a_{jk,corr}$ is the corrected deceleration, expressed in m/s^2 (see EN 16834);
 - $a_{jk,meas}$ is the deceleration derived from test, expressed in m/s^2 (see EN 16834);
 - i_m is the mean gradient in accordance with EN 16834:2019, 6.7.1;
 - W_{Bo} is the mean curve resistance in accordance with EN 16834:2019, 6.7.1;
 - g is the acceleration due to gravity;
 - ρ is the coefficient of inertia of the rotating masses in accordance with EN 16834:2019, 6.7.1;
- ALTERNATIVE:
coefficient of inertia of the rotating masses, which is defined in Formula (10)

$$\rho = 1 + \frac{m_r}{m} \quad (10)$$

where

- m is the static mass of the train or test vehicle (see EN 16834);
- m_r is the equivalent mass of the rotating components (see EN 16834).

It is not necessary to correct the initial speed measured in the test.

7.2.2.8 Correction factors dedicated to constant decelerations a_{bi}

The constant decelerations $A_{nominal}$ applicable during the speed interval between v_i and v_{i+1} (see EN 16834:2019, 7.2) are determined as refers to the vehicle in its tested condition. To determine decelerations, this result relating to the tested condition of the vehicle shall be corrected to the nominal condition. The procedure described hereafter can only be used for brakes where the braking force is transmitted exclusively via the wheel/rail interface, i.e. excludes magnetic track brakes or eddy current brake. The following factors are considered in this context:

- a) Dynamic efficiency of brake rigging on test vehicle in relation to the nominal value foreseen for operations. For dynamic brakes the correction factor in relation to brake rigging efficiency is not relevant.
- b) In the case of disc-braked test vehicles; the average wheel diameter, in relation to the diameter of the new wheel. If dynamic brakes are considered, the correction factor in relation to the wheel diameter is applicable if the dynamic brake force is dependent from the wheel diameter. For wheels fitted with block brakes, it is not necessary to correct the wheel diameter.
- c) In the event that the brake cylinder pressure on the test vehicle deviates from the nominal value assumed for the design series, a correction within a maximum tolerance range of $\pm 0,2$ bar shall be applied.

For trains equipped with a brake system using a single type of pneumatic brake units, correction should be made using Formula (11).

$$a_{bj,corr} = a_{bj,test} \times \frac{\eta_{dyn}}{\eta_{dyn,test}} \times \frac{d_{test}}{d_{new}} \times \left(\frac{p_{nom} - p_{spring}}{p_{test} - p_{spring}} \right) \quad (11)$$

where

- d_{test} is the average wheel diameter on test vehicles, expressed in mm (see EN 16834);
- d_{new} is the diameter of new wheel, expressed in mm; for block braked wheels $d_{test} = d_{new}$ (EN 16834);
- p_{nom} is the nominal brake cylinder pressure, expressed in bar (see EN 16834);
- p_{test} is the actual brake cylinder pressure during the test, expressed in bar (see EN 16834);
- p_{spring} is the equivalent pressure to compensate the force of the retainer spring, expressed in bar ($p_{spring} = p_{Feder}$ in EN 16834);
- $a_{bj,corr}$ is the corrected nominal deceleration during the speed interval between v_i and v_{i+1} , expressed in m/s^2 (EN 16834);
- $a_{bj,test}$ is the nominal deceleration derived from tests during the speed interval between v_i and v_{i+1} , expressed in m/s^2 (see EN 16834);
- η_{dyn} is the nominal dynamic efficiency of brake rigging (see EN 16834);
- $\eta_{dyn,test}$ is the dynamic efficiency of brake rigging during test.

To ensure that new vehicles also deliver the determined deceleration, the factor $\frac{\eta_{dyn}}{\eta_{dyn,test}} \times \frac{d_{test}}{d_{new}}$ shall be restricted to values ≤ 1 when performing corrections for tests on new vehicles.

For brake systems using a combination of brake unit's types, the correction of the deceleration should be done considering the weight of each brake unit braking force in the total braking force.

7.2.3 Determination by calculation

7.2.3.1 Normal mode

The determination of nominal deceleration by means of calculation is the same for both approaches A and B since the normal mode testing is the same for both approaches.

Determination of parameter values for certain brake control/type combinations with brake calculations are only allowed when results from dynamic brake tests, from the default brake control/type combinations (see 7.2.2.4, Table 4), give sufficient detailed and validated information (by corrections applied to information from dynamic brake tests) for the brake performance of the separate brake control/type systems used in the considered combination. When needed, e.g. for calculations of multiple unit operation, the brake performance of brake systems without resistance against forward movement can be calculated. This calculation is done in a brake calculation by subtracting the effect of the resistance against forward movement (as calculated in accordance with EN 16834:2019, 6.7.3.2.5) from the data that is validated by means of dynamic brake testing (see 7.2.2.4).

The detailed validated information of a separate brake control/type system can be considered as validated building block for brake calculations for other combinations. Resulting in indirect validated brake calculations for any combination that can be made from the validated separate building blocks. E.g. when dynamic brake tests are performed with only the main brake system and with the main brake system plus magnetic track brakes this gives validated information for both the main system and the magnetic track brakes since the separate magnetic track brake information can be derived from the relative difference.

When also dynamic brake tests are done with the main brake system (or main brake system plus magnetic track brakes) and other additional brake system, this gives validated information for this additional system (by relative comparison). In that case any variation in the combination of brake systems from these three brake systems no longer needs to be validated with dynamic brake tests, but the results can be calculated from brake calculations for given combinations. The same principle applies when more than three brake systems would be applicable.

7.2.3.2 Degraded mode

The validated information from dynamic brake testing for all degraded modes with just one degraded brake system forms the building block for brake calculations for other combinations of degraded mode. Since per system of the same type that can be degraded the highest contribution factor is tested, a deduction of multiple systems of the same type will be always a worst-case, hence safe, approximation. With this method parameter values for any other degraded mode combination can be made.

Alternatively, parameter values for any degraded mode combination can also be derived from brake calculations using the same correction factors, derived to create the validated separate building blocks from the dynamic testing, to other systems of the same type of degraded brake system. Applying the same correction factors to other (not tested) train parts also results in validated building blocks, since these are indirectly validated by being similar to the validated degraded system.

7.2.3.3 Criteria for validated brake calculation

For brake calculations based on validated building blocks, the validation can be done either by performing new dynamic braking tests (see 7.2.2) or using pre-existing dynamic brake test data. For building blocks that can be validated by using pre-existing data, no additional dynamic brake tests are needed.

A brake calculation building block is validated when two types of criteria are met:

- a) dynamic brake testing values are within acceptable limits of the nominal configuration (as used in the brake calculation);

b) brake calculation results are within acceptable limits of the dynamic brake testing results.

Criterion a) is met when all relevant braking subcomponents and -systems are normally operational and their test values are in the normal maintenance tolerance and within following limits:

- conditions of EN 16834:2019, 6.4.3;
- average brake cylinder pressures (per relevant speed interval, e.g. for high/low pressure systems): test values within $\pm 0,2$ bar of nominal values AND friction brake application force (including efficiency) within ± 5 % of the component's nominal values;
- if applicable, average ED brake forces (per relevant speed interval): test values within ± 5 % of traction unit's nominal ED brake force values.
- if applicable, average eddy current brake air gap with the rail: test values within ± 1 mm of nominal values in component's technical specification,
- average equivalent brake response times (per relevant speed interval, e.g. for high/low pressure systems and per relevant brake systems configuration): test values within ± 10 % of nominal values.

Criterion b) is met when the brake calculation results are within the following limits:

- for initial speeds ≤ 30 km/h: calculated stopping distances are within 0 to +5 m of the dynamic brake test results;
- for initial speeds > 30 km/h: calculated stopping distances are within 0 to max (+5 m, +5 %) of the dynamic brake test results;
- in normal mode, calculated decelerations on each speed range are within ± 10 % of the measured deceleration (see EN 16834:2019, 7.3.2.2 – average deceleration) on the same speed range from the dynamic brake tests, when brakes are fully established;
- in degraded mode, calculated decelerations on each speed range are a maximum 10 % lower than the measured deceleration (see EN 16834:2019, 7.3.2.2 – average deceleration) on the same speed range from the dynamic brake tests, when brakes are fully established.

As long as criteria a) and b) are met, all brake calculations built from validated building blocks can be considered as validated brake calculations.

7.2.4 Determination at degraded conditions

The nominal deceleration shall not cover degraded conditions (see SUBSET-040 [12], 4.4.1.2.1 environmental conditions and 4.4.1.2.2 humidity of friction elements). Therefore, no rules for nominal decelerations at degraded conditions are necessary.

The ETCS Gamma model provides a vehicle related solution to handle some degraded adhesion condition situations via use of $K_{wet}(C,V)$ (see 7.4).

7.2.5 Determination for multiple unit operation

Validated deceleration data of single train operation, e.g. validated data of a trainset, can be used to determine the deceleration data for multiple unit operation via brake calculations. In that case the resistance against forward movement of the dynamic brake tests shall be modified into the effect for the combination used in multiple unit operation. This modified effect is then to be used in the brake calculation (in combination with the brake systems performance without this effect).