PUBLICLY AVAILABLE SPECIFICATION

ISO/PAS 5101

First edition
2021-10

Road vehicles — Field load specification for brake actuation and modulation systems

Véhicules routiers — Spécification de la charge pour les systèmes d'actionnement et de modulation des freins

Reference number
ISO/PAS 5101:2021(E)

Contents

Page

Foreword iv
Introduction v
1 Scope 1
2 Normative references 1
3 Terms and definitions 1
4 General 2
5 Percentiles of field coverage 3
6 Base assumptions and boundary conditions 4
6.1 General 4
6.2 Lifetime specifications 4
6.2.1 Vehicle lifetime 4
6.2.2 Standstill events, slopes and durations 5
6.2.3 Standstill duration distribution 5
6.2.4 Brake duration distribution 5
6.3 Number of brake operations 6
6.4 Temperature distributions 7
6.4.1 Global environmental temperature distribution T_{env} 7
6.4.2 Temperature distribution at installation location T_{inst} 8
6.4.3 Exceptional high temperatures at the installation location 9
6.4.4 Function specific occurrence and distributions over temperature ranges 10
6.5 Brake pedal application profile 11
6.5.1 Parameters for brake pedal apply and release time 11
6.5.2 Modulation of deceleration during brake events 12
7 Braking system usage 13
7.1 Base brake function 13
7.2 Dynamic stability functions 14
7.2.1 Electronic brake force distribution (EBD) 14
7.2.2 Antilock braking system (ABS) 14
7.2.3 Traction control (TCS) 16
7.2.4 Electronic stability control (ESC) 20
7.2.5 Trailer sway control (TSC) 24
7.2.6 Roll-over mitigation functions 24
7.3 Brake torque optimizing functions 25
7.3.1 Brake booster support functions 25
7.3.2 Hydraulic brake assist (HBA) 36
7.3.3 Hydraulic rear-brake boost (HRB) 37
7.3.4 Fading support 37
7.3.5 Brake preconditioning 38
7.4 Assistance functions 40
7.4.1 Standstill management 40
7.4.2 Hill descent control 45
7.4.3 Adaptive cruise control (ACC) 46
7.4.4 Parking assist (PA) 51
8 Substitution methods 55
8.1 Dependent functions 55
8.1.1 Substitution of ABS functions 55
8.1.2 Substitution of hold functions 56
8.1.3 Substitution of fading support manoeuvres 57
8.1.4 Substitution of brake disc wiping manoeuvres 57
8.1.5 Substitution of base brake functions 58
Bibliography 59

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Vehicle development programs tend to grow in complexity and integration of the braking system with chassis dynamics and mechatronics, demanding more robust and comprehensive evaluation programs. Also, to remain competitive, braking systems and their components' functionality and application across multiple vehicle architectures and platforms are increased.

The proper selection and adaptation of field load spectra and profiles to the specific program ensure functionality, reliability and braking system availability. This document defines a library of field load schedules to help developing simulation and testing programs tailored to the vehicle or system specification and requirements. Specific cycles and load collectives including the main functions associated with everyday driving and operation and exceptional load cases are described to ensure safe braking behaviour. This document's field load was typically derived from analysing field data collected from almost 1 million vehicles having driven more than 45 billion km. Several vehicle and brake system suppliers from vehicles used in different regions worldwide contributed to this field data collection. In addition, data from driving studies with specific measurement equipment was used. Wherever the data available from field or studies was not sufficient, existing specifications or expert judgement served to derive conservative assumptions.

This document provides field loads independent of the vehicle technology, vehicle specification, intended use and field usage. It remains the manufacturer's responsibility to include and adapt the field loads to the specific vehicle configuration. The adaptation includes at least:

— define sampling and testing plans, including vehicle configuration(s), road conditions selection of the specific profiles and load spectra of this document;

— define level of evaluation and integration of simulation, Hardware-in-the-Loop, physical testing methods, along with other components and software functions part of the testing program;

— agree on performance and reliability criteria (including statistical tools and metrics);

— reflect specific system architectures and control technologies for the unit(s) under testing.

Road vehicles — Field load specification for brake actuation and modulation systems

1 Scope

This document specifies expected field loads for functions provided by the braking system actuator and modulator and applies to passenger cars and light commercial vehicles (classes M1 and N1, according to UNECE).

Functions addressed in this document are:

— dynamic stability functions (e.g. electronic stability control);

— brake torque optimizing functions (e.g. electronic brake force distribution);

— brake assistance functions (e.g. hill start assist).

This document only covers functions where data of appropriate maturity are available. There are additional functions of a braking system, which are not covered by this document.

By describing the expected field loads, this document specifies representative manoeuvres and occurrences for different functions. These serve as an orientation for the derivation of test procedures.

This document applies to vehicles up to conditional automation (SAE J 3016 level 3) with a maximum of 30 % automated brake operations.

NOTE Field loads for automation levels above level 3 are under consideration for future editions.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
brake booster
part of the actuation unit, excluding master cylinder, in systems with separate actuator and modulator

Note 1 to entry: A brake booster is not part of braking systems with integrated actuator and modulator (see Figure 1).

3.2
fading
decrease of braking torque as a function of temperature or vehicle speed at constant application force

Note 1 to entry: Amongst others, the decrease of the friction by the temperature is the most important effect.

[SOURCE: ISO 611:2003, 7.1.7, modified — The original term was "brake fade", the word “vehicle” and Note 1 to entry were added, and the examples were removed.]

3.3
brake friction coefficient
ratio between the tangential force and the normal force, acting between linings and drum or disc

[SOURCE: ISO 611:2003, 9.19.1, modified — The symbols and formula were removed, the original term was "coefficient of friction".]

3.4
coefficient of adhesion
μ
ratio between the tangential force transmitted to the road by a tyre and the normal force

[SOURCE: ISO 611:2003, 9.19.2, modified — "k" was changed to "μ", the symbols, formula and note were removed.]

3.5
control time
duration the braking system is controlling the pressure

3.6
fully active brake operation
deceleration intended by the driver and automatically initiated and operated by the braking system

3.7
nominal runout pressure
lowest master cylinder pressure where maximum support from the actuator is reached in quasi-static operation

Note 1 to entry: Only applies to separated actuator and modulator.

Note 2 to entry: For vacuum-based actuation systems, the nominal runout pressure refers to sea level.

Note 3 to entry: Above this pressure, only the unsupported pressure increase is possible.

3.8
partially active brake operation
deceleration initiated by the driver and supported by the modulation of the wheel brake pressure

3.9
standstill
stopping situation during a trip in which the vehicle is not moving

EXAMPLE Stopping at traffic lights or in heavy traffic situations.

Note 1 to entry: Standstill does not include parking situations.

3.10
steering angle
mean value of angle of left and right front wheel relative to the longitudinal axis of the vehicle

Note 1 to entry: Rear-wheel steering is not considered in this document.

4 General

This document describes use cases represented by manoeuvres and their occurrences for various functions of the braking system to describe the expected field loads for a braking system. Unless otherwise specified, these manoeuvres and occurrences are derived from empirical values and collected field data.

The manoeuvres and occurrences described in this document serve as an orientation to develop test procedures. The applicability of the generalized field loads detailed in this document needs to consider the specific braking system and vehicle configuration.

Figure 1 depicts the components of the braking system addressed in this document.

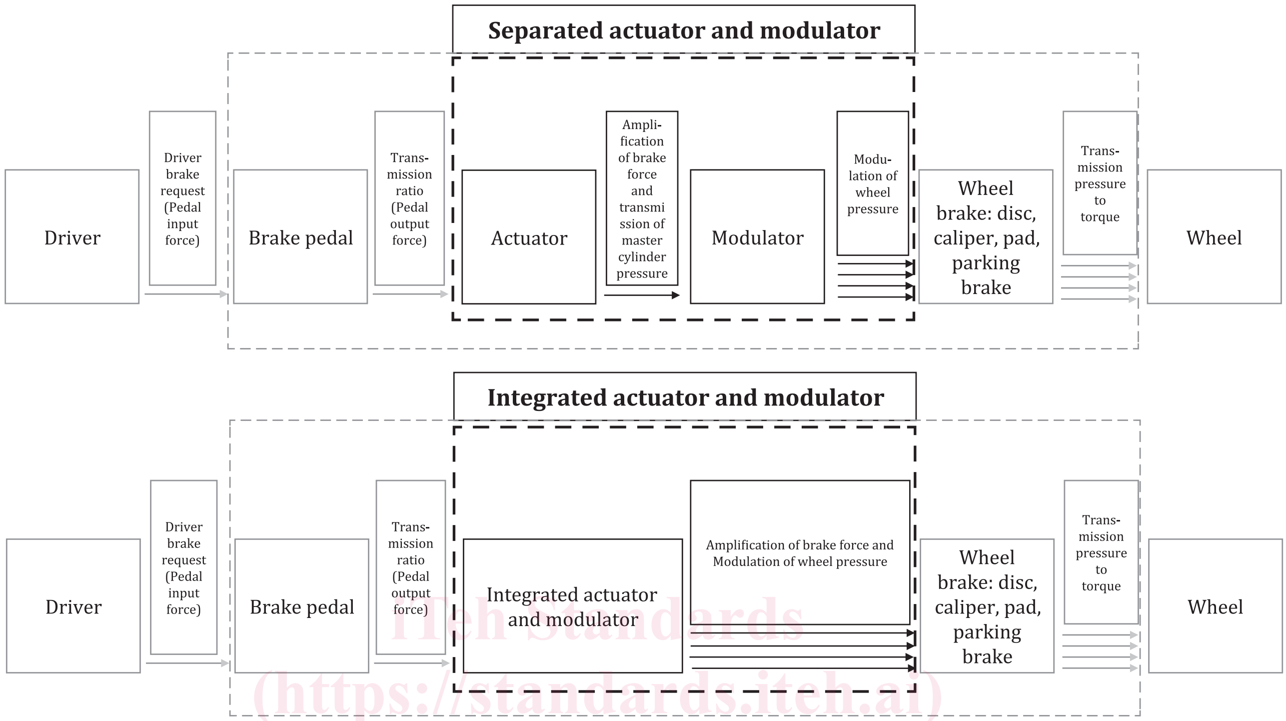


Figure 1 — Components of the braking system

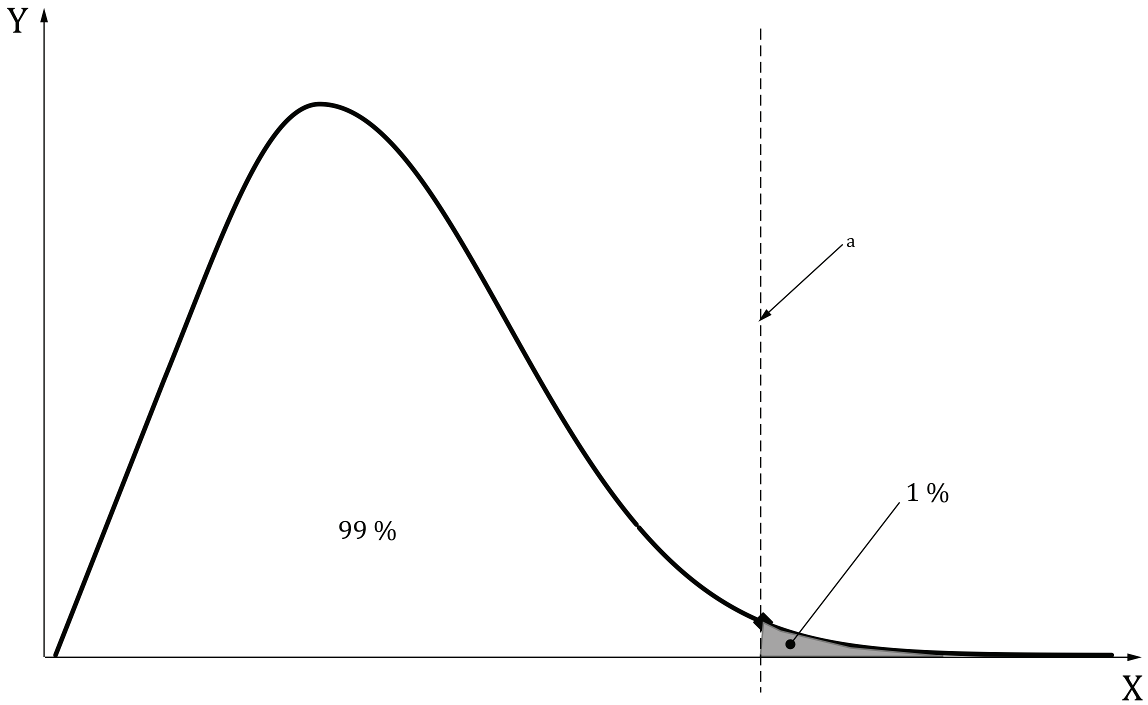
5 Percentiles of field coverage

The braking system supports multiple vehicle dynamics functions. The probability of high usage of all functions in an individual vehicle is much lower than the probability of high usage of only one single function in an individual vehicle. A specification aiming to cover the 100th percentile vehicle for every individual function would lead to an over-specification.

The field load for electronic brake force distribution (EBD), antilock braking system (ABS) and adaptive cruise control (ACC) aims to describe the 99th percentile vehicle usage. All other functions described in Clause 7 cover the 95th percentile vehicle usage for each function. However, it is unlikely that all functions – given the multitude of functions - are used up to the specification limit in one individual vehicle. This approach leads to a field coverage significantly above 99 %.

NOTE 1 ABS, EBD and the standard brake function are specified to cover the 99th percentile vehicle usage because products only providing this set of functions exist and therefore, the combination effect is weak. ACC is specified to cover the 99th percentile because it is an automation of the standard braking function.

Figure 2 illustrates an example of the usage of an individual function.



Key

X load or stress level with consistent engineering units

Y probability density

[a] 99th percentile.

Figure 2 — Schematic example of the probability density function *P* for the load *σ*

NOTE 2 Few vehicles experience a very low load; few vehicles experience a very high load; most vehicles experience a medium level of load.

NOTE 3 Typically, braking system components can endure loads above their specification. Furthermore, the load a component experiences is typically lower than the load described.

6 Base assumptions and boundary conditions

6.1 General

This clause defines the assumptions for the vehicle lifetime and braking system lifetime. These assumptions serve as the baseline for the manoeuvres and occurrences of the functions described in Clause 7.

NOTE Clause 7 describes the field load for braking system functions but not for wearing parts such as brake pads and brake discs.

6.2 Lifetime specifications

6.2.1 Vehicle lifetime

The field loads described in this document correspond to a vehicle lifetime of either 300 000 km or 8 000 h ignition-on time or 15 years, whichever occurs first.

The expected amount of trips is up to 50 000 over a vehicle lifetime.

6.2.2 Standstill events, slopes and durations

The expected amount of brake operations that lead to a standstill is 480 000 over a vehicle lifetime. Table 1 shows the distribution of slopes at the standstill events. The values shown include uphill and downhill slopes and cover the 99th percentile. An even distribution between up- and downhill situations is assumed.

Table 1 — Distribution of standstill events versus slope angle

Slope at a standstill [%]	Probability [%]
> 30 - 50	0,006
> 20 - 30	0,194
> 15 - 20	0,8
> 10 - 15	2
> 5 - 10	9
≤ 5	88

6.2.3 Standstill duration distribution

In total 480 000 standstill events are defined over vehicle lifetime. Table 2 shows the distribution of their duration. The durations are independent of any active function when the vehicle ignition is on. The distribution covers the 99th percentile usage.

NOTE The parking times between two trips are not considered.

Table 2 — Distribution of standstill duration

Standstill duration [s]	Frequency
0 - 2	126 000
2 - 10	162 000
10 - 30	100 000
30 - 60	47 000
60 - 180	34 000
180 - 900	9 000
> 900	2 000
Sum	**480 000**

6.2.4 Brake duration distribution

Table 3 shows values of the brake duration distribution of an average driver.

Table 3 — Distribution of brake duration

Brake duration [s]	Percentage per class [%]
0 – 2	57
2 – 5	25
5 - 10	9
10 - 60	8
> 60	1
Sum	**100**

6.3 Number of brake operations

Over a vehicle lifetime, the 99th percentile of brake operations corresponds to 2,2 million brake operations. Of these 2,2 million brake operations, 600 000 events take place during standstill.

The frequency of brake operations during standstill represents brake operations that begin and end during vehicle standstill.

Table 4 shows the number of brake operations in deceleration classes of 0,05 *g*.

The frequencies shown in Table 4 include the base brake function and all functions intended to decelerate or hold the vehicle.

This document assumes 10 000 kPa is equivalent to 1,0 *g* for a typically laden vehicle.

Table 4 — Distribution of brake operations versus deceleration and brake pedal force

Deceleration [*g*]	Brake pedal force [N]	Frequency per class while driving [a]	Frequency per class during standstill	Frequency per class
0,00 ≤ x ≤ 0,05	20	205 033	84 569	289 602
0,05 < x ≤ 0,10	20	639 927	243 706	883 633
0,10 < x ≤ 0,15	29	404 300	115 070	519 370
0,15 < x ≤ 0,20	38	200 177	56 182	256 359
0,20 < x ≤ 0,25	48	84 266	25 350	109 616
0,25 < x ≤ 0,30	57	35 147	16 912	52 059
0,30 < x ≤ 0,35	67	14 463	12 771	27 234
0,35 < x ≤,0,40	77	7 168	9 810	16 978
0,40 < x ≤ 0,45	86	3 893	7 793	11 686
0,45 < x ≤ 0,50	96	2 144	5 892	8 036
0,50 < x ≤ 0,55	105	1 252	4 585	5 837
0,55 < x ≤ 0,60	115	745	3 474	4 219
0,60 < x ≤ 0,65	124	466	2 718	3 184
0,65 < x ≤ 0,70	134	332	2 218	2 550
0,70 < x ≤ 0,75	143	198	1 613	1 811
0,75 < x ≤ 0,80	153	91	1 067	1 158
0,80 < x ≤ 0,85	163	77	995	1 072
0,85 < x ≤ 0,90	172	63	917	980
0,90 < x ≤ 0,95	182	52	831	883
0,95 < x ≤ 1,00	191	41	739	780
1,00 < x ≤ 1,05	201	32	640	672
1,05 < x ≤ 1,10	210	25	534	559
1,10 < x ≤ 1,15	220	19	421	440
1,15 < x ≤ 1,20	230	14	301	315
1,20 < x ≤ 1,25	239	10	175	185
1,25 < x ≤ 1,30	249	9	105	114
> 1,30	> 250	56	612	668
		1 600 000	**600 000**	**2 200 000**

[a] Including brake operations leading to a vehicle standstill.

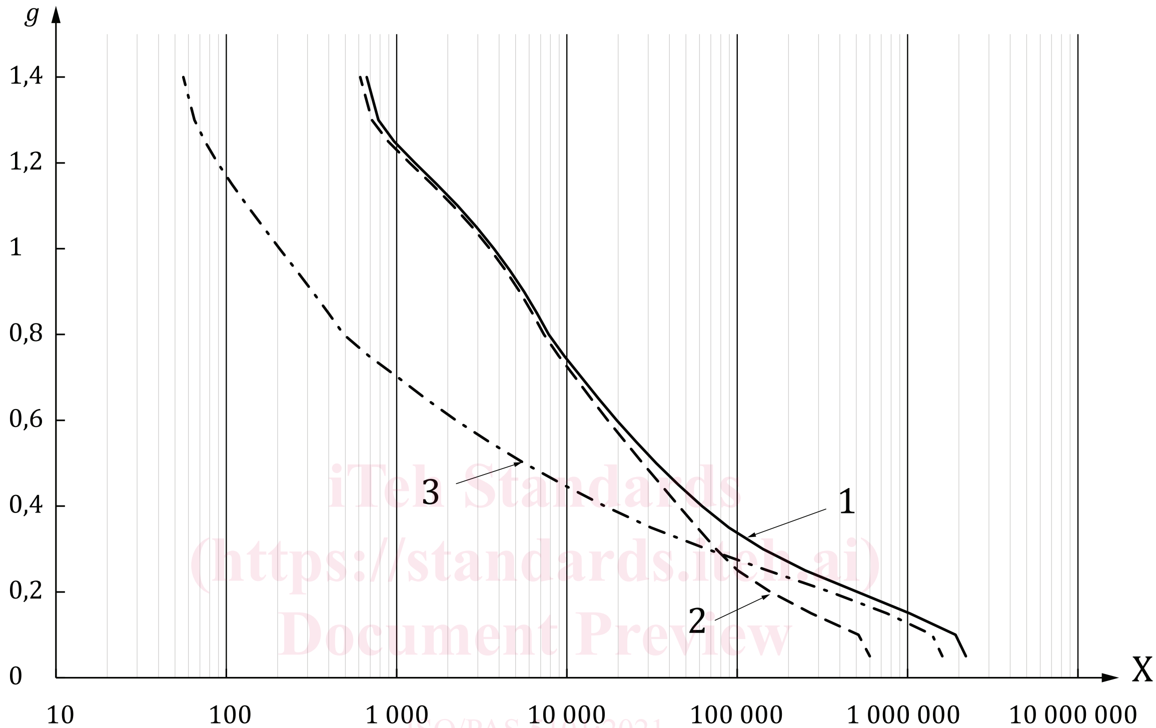
NOTE 1 Table 4 shows data over a vehicle lifetime according to 6.2.1.

NOTE 2 Brake pedal forces are derived from the deceleration to brake pedal force characteristic of vehicles which delivered the corresponding field data.

NOTE 3 Brake pedal forces values are used for brake pedal applies during standstill, deceleration values for brake pedal applies during driving.

NOTE 4 For vehicle configurations differing from those assumptions, the relation between brake pressure and deceleration is determined individually.

Figure 3 illustrates the corresponding cumulative distributions from Table 4.



Key

X cumulative number of load cycles in counts

g deceleration level in *g*

1 total cumulative brake operations

2 cumulative brake operations while driving

3 cumulative brake operations during standstill

Figure 3 — Cumulative distribution per class

6.4 Temperature distributions

6.4.1 Global environmental temperature distribution T_{env}

The distribution of the environmental temperatures, as shown in Table 5, uses the following principles:

— global coverage of typical, low and high-temperature profiles;

— weighting according to human population density, cities with less than 1 000 inhabitants are not considered;

— extreme temperature events, which do not occur regularly within 10 years, are not covered.

Table 5 — Distribution of environmental temperature

T_{env} [°C]	Probability [%]
– 40	0,5
– 30	2
– 20	5
– 10	5
0	7,5
10	15
20	25
30	25
40	14
50	1
Sum	**100**

6.4.2 Temperature distribution at installation location T_{inst}

Table 6 provides the estimated probability distribution as a function of the temperature at the installation location T_{inst}.

The temperature at installation location T_{inst} reflects the superposition of the environmental temperature T_{env} outside the vehicle with the temperature increase dT at the installation location in a combustion engine compartment during vehicle operation.

The dT in electric vehicles is lower and therefore is assumed to be covered by this specification. Use Formula (1) to determine the temperature distribution at the installation location.

$$T_{inst} = T_{env} + \Delta T \tag{1}$$

where

- T_{inst} is the temperature at the installation location of the brake actuation and modulation systems;
- T_{env} is the distribution of worldwide environmental temperature outside the vehicle (vehicle independent, see 6.4.1);
- ΔT is the temperature increase by vehicle usage at installation location (vehicle dependent, typical vehicle resulting distribution for T given in Clause 6).

At environmental temperatures of -40 °C, no increase of T_{inst} by vehicle usage is assumed due to the airflow's high cooling capability.

Moderate and high environmental temperatures lead to a ΔT of up to 55 K.

Specific temperature effects may be considered when the brake system components directly interact (have thermal conductivity) through a mechanical connection.

EXAMPLE Direct cooling effect by the connection of an actuator to the passenger compartment.