



BSI Standards Publication

Railway applications — Air conditioning for urban, suburban and regional rolling stock: Comfort parameters and type tests

National foreword

This British Standard is the UK implementation of EN 14750:2024. It supersedes BS EN 14750-1:2006 and BS EN 14750-2:2006, which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RAE/4/-/3, Railway Applications - Air conditioning, Heating and Ventilation.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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**Railway applications - Air conditioning for urban,
suburban and regional rolling stock: Comfort parameters
and type tests**

Applications ferroviaires - Conditionnement de l'air
pour matériel roulant urbain, de banlieue et régional :
Paramètres de confort et essais de type

Bahnanwendungen - Luftbehandlung in
Schienenfahrzeugen des städtischen-, Vorort- und
Regionalverkehrs - Behaglichkeitsparameter und
Typprüfungen

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European foreword

This document (EN 14750:2024) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2025, and conflicting national standards shall be withdrawn at the latest by June 2025.

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

This document supersedes EN 14750-1:2006 and EN 14750-2:2006.

In comparison with the previous edition, the following technical modifications have been made:

- Creation of 3 vehicle categories (Urban, Suburban and Regional) to define the corresponding performances;
- Definition of normal and extended ranges of exterior temperatures with corresponding performances;
- Usage of an index Comfort Level (CL) to provide a global view of the climatic comfort;
- Improvement of the validation process with new regulation tests. The purpose is to assess the quality of the regulation of the system;
- Introduction of the process of validation of the climatic comfort parameters by simulations.

This document has been prepared under a Standardization Request addressed to CEN by the European Commission.

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

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1 Scope

This document establishes thermal comfort parameters for areas accessible to passengers and staff on railway vehicles.

This document also specifies conditions, performance values and the comfort parameter validation methods.

This document is applicable to urban (metro, tramway), suburban and/or regional vehicles equipped with cooling and/or heating/ventilation systems. This document does not apply to main line vehicles and driver's cabs which are considered in separate Standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all 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 ISO 7726:2001, *Ergonomics of the thermal environment — Instruments for measuring physical quantities (ISO 7726:1998)*

EN ISO 19659-1:2023, *Railway applications — Heating, ventilation and air conditioning systems for rolling stock — Part 1: Terms and definitions (ISO 19659-1:2017)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 19659-1:2023 and the following apply.

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

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

NOTE Refer to informative Annex R for more information on abbreviations.

3.1 air conditioning installation

all equipment of Heating Ventilation Air Conditioning (HVAC) system involved to reach the thermal comfort

Note 1 to entry: Refer to EN ISO 19659-1:2023.

3.2 interior temperature setpoint

T_{ic}
target value for interior air temperature

3.3 normal interior temperature setpoint

$T_{ic,0}$
target value for interior air temperature according to regulation curve

Note 1 to entry: Refer to 9.2 and normative Annex B.

3.4**interior temperature setpoint offset** $T_{ic,off}$

adjustment of the interior temperature setpoint

Note 1 to entry: Refer to 9.2.

3.5**mean interior temperature** T_{im}

arithmetic mean of the interior temperatures of one comfort zone and measured 1,10 m above the floor as specified in the procedure described in normative Annex K

3.6**mean exterior temperature** T_{em}

arithmetic mean of the exterior temperatures measured according to the procedure described in normative Annex M

3.7**comfort envelope**

areas designed for occupation by passengers, excluding local annexes

Note 1 to entry: If a gangway is designed for passengers to dwell inside, it is part of comfort envelope.

3.8**comfort zone**

subset of the comfort envelope on one vehicle limited by steps or ramp with a total floor height difference of at least 0,3 m, partition wall, vestibule, interior door or gangway

Note 1 to entry: Tram is considered as one comfort zone.

Note 2 to entry: The comfort zone is divided in subzones to define the position of the measuring points (refer to normative Annex K especially Figure K.1 for the description of the subzones).

3.9**local annex**

place where passenger stays briefly or passes through

EXAMPLE 1 toilet compartment (WC)

EXAMPLE 2 baby change area

EXAMPLE 3 aisle

EXAMPLE 4 vestibule

Note 1 to entry: If a gangway is closed by two doors it is not considered as a local annex and no comfort criterion is applied.

Note 2 to entry: For multi-purpose areas, the classification as comfort zone or local annex have to be agreed.

3.10

heat transfer coefficient

k

ratio between the thermal power per unit of surface area and the prevailing difference in temperature (T_{im}) and (T_{em}) across the relevant walls of the vehicles

Note 1 to entry: The coefficient k takes account of the efficiency of the insulation of the exterior walls and the effect of the infiltration of air caused by the non-airtightness of the vehicle in motion (doors, windows, various openings) and is applicable to all or part of the vehicle.

Note 2 to entry: This value is expressed in $W/(m^2 \cdot K)$.

3.11

equivalent solar irradiation

total heat received by 1 m^2 surface perpendicular to the radiation emitted by a luminous source (solar equivalent) and this, when inclined at an angle of 30° to the horizontal

3.12

stand by operation

mode under which a predetermined interior temperature range is maintained when the vehicle is not in commercial service

3.13

design passenger load

number of passengers used to size the air conditioning installation

3.14

free cooling

provision of cooling using potential increase of fresh airflow and without use of refrigerant circuit

3.15

vestibule

area with at least one exterior door separated from the comfort envelope by steps or ramp with a total floor height difference of at least 0,3 m, interior door(s), full partition wall(s) and without permanent seats

3.16

mean interior CO₂ concentration

C_{im}

arithmetic mean of the interior CO₂ concentration measured at the centre of each subzone of each comfort zone and at the height of 1,1 m

Note 1 to entry: Refer to normative Annex K.

3.17

climatic zone

climatic conditions used to size the HVAC system

Note 1 to entry: Refer to 7.1, 7.2 and 7.3 for the definition of design and the extreme conditions.

3.18
mean interior absolute humidity

x_{im}
arithmetic mean of the absolute humidity calculated with the local relative humidity and corresponding temperature of the comfort zone measured at 1,1 m above the floor as specified in normative Annex K

3.19
mean interior relative humidity

RH_{im}
relative interior humidity calculated with the interior mean temperature (T_{im}) and absolute interior humidity (x_{im}) per comfort zone

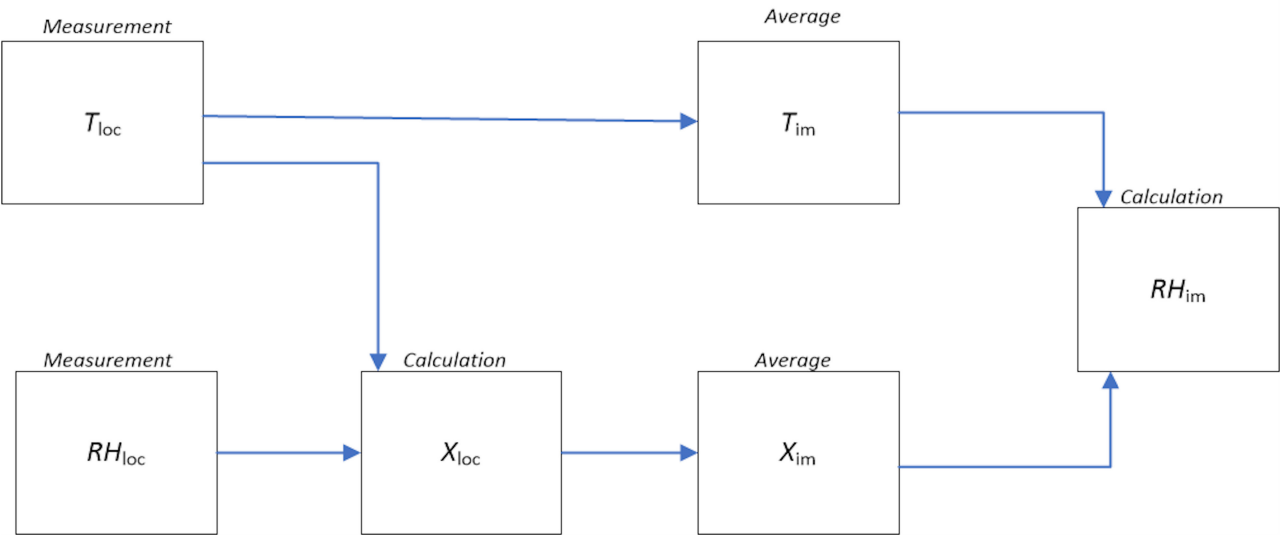


Figure 1 — Process to calculate RH_{im}

Note 1 to entry: The absolute humidity is given by Formula (1):

$$X_{Loc} = \frac{0,622 \times RH_{Loc} \times P_{Sat_Loc}}{100 \times P_{Atm} - RH_{Loc} \times P_{Sat_Loc}} \tag{1}$$

Where

- X_{Loc} Local absolute humidity in kilogram of water per kilogram of dry air [kg of water/kg dry air];
- RH_{Loc} Local relative hygrometry in percentage [% value from 0 to 100];
- P_{Sat_Loc} Local pressure of saturated steam calculated with T_{Loc} in pascals [Pa];
- P_{Atm} Local atmospheric pressure in pascals [Pa];
- T_{Loc} Local temperature in Celsius degrees [°C].

Note 2 to entry: The pressure of saturated steam is given by the Formula (2):

$$P_{Sat_Loc} = 1000 \times e^{\left(16,6536 - \frac{4030,183}{T_{Loc} + 235}\right)} \quad (2)$$

Where

P_{Sat_Loc} Local pressure of saturated steam in pascals [Pa];

T_{Loc} Local temperature in Celsius degrees [°C].

EXAMPLE 1 At $T_{em} = 35^\circ\text{C}$ 50 % at atmospheric pressure of 101 325 Pa, $P_{Sat} = 5\,623,7$ Pa corresponds to $X = 0,017\,75$ kg of water/kg dry air or 17,75 g of water/kg dry air.

Note 3 to entry: The mean interior temperature is given by the Formula (3):

$$T_{im} = \frac{1}{N} \sum_{i=1}^N T_{Loc_i} \quad (3)$$

Where

T_{im} Mean interior temperature in Celsius degrees [°C];

N Number of local temperature involved in mean interior temperature calculation [number];

T_{Loc_i} Local temperature in Celsius degrees [°C].

Note 4 to entry: The mean interior absolute humidity is given by the Formula (4):

$$X_{im} = \frac{1}{N} \sum_{i=1}^N X_{Loc_i} \quad (4)$$

Where

X_{im} Mean interior absolute humidity in kilogram of water per kilogram of dry air [kg of water/kg dry air];

N Number of local absolute humidity involved in mean interior absolute humidity calculation [number];

X_{Loc_i} Local absolute humidity in kilogram of water per kilogram of dry air [kg of water/kg dry air].

Note 5 to entry: The mean relative hygrometry is given by the Formula (5):

$$RH_{im} = \frac{100 \times X_{im} \times P_{Atm}}{P_{Sat_im} \times (0,622 + X_{im})} \quad (5)$$

Where

RH_{im} Mean relative hygrometry in % [value from 0 to 100];

X_{im} Mean absolute humidity in kilogram per kilogram of dry air [kg of water/kg dry air];

P_{Atm} Local atmospheric pressure in pascals [Pa];

P_{Sat_im} Pressure of saturated steam calculate with the mean interior temperature in pascals [Pa].

EXAMPLE 2 In one comfort zone we have these measurements of temperature and relative humidity on 9 points (refer to Table 1). The atmospheric pressure is 101 325 Pa.

Table 1 — Parameters considered in the example

	Unit	1	2	3	4	5	6	7	8	9
TLoc	°C	25,1	25,2	24,7	24,8	25,5	24,1	24,5	26,1	25,3
RHLoc	%	50,8	55,6	57,3	54,8	56,9	59,2	56,1	48,1	48,9
PSat_Loc	Pa	3186,3	3205,3	3111,1	3129,8	3263,0	3001,3	3074,2	3381,1	3224,5
XLoc	kg of water/kg dry air	0,0101	0,0111	0,0111	0,0107	0,0116	0,0111	0,0108	0,0101	0,0098

Note 6 to entry: The calculated values are indicated in Table 2:

Table 2 — Calculated values in the example

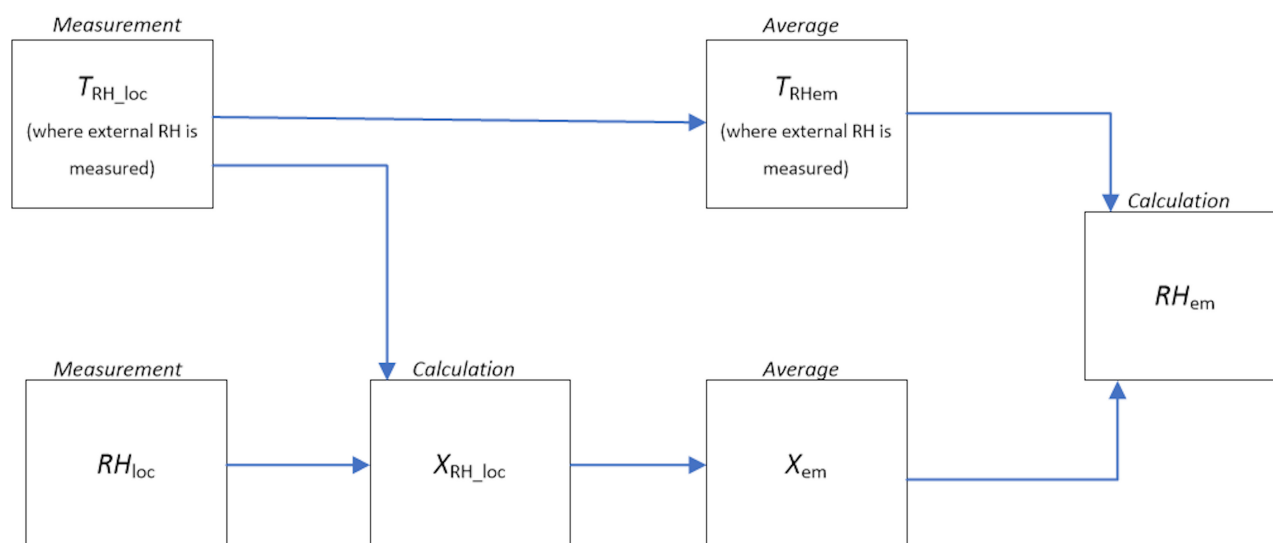
	Unit	Value
T_{im}	°C	25,0
X_{im}	kg of water /kg dry air	0,0107
P_{Sat_im}	Pa	3173,7
RH_{im}	%	54,1

3.20
mean exterior absolute humidity

x_{em}
arithmetic mean of the absolute humidity calculated with the local relative humidity RH_{Loc} and corresponding temperature as specified in normative Annex M

3.21
mean exterior relative humidity

RH_{em}
relative exterior humidity calculated with the exterior mean temperature (T_{em}) and absolute exterior humidity (x_{em})

Figure 2 — Process to calculate RH_{em} **3.22****subzone**

portion of the comfort zone only used for the location of the test sensors

3.23**mean air speed of vehicle surrounding flow**

arithmetic mean of the air speed measured at 6 points outside the vehicle at the distance of 0,1 m from the wall of the vehicle

Note 1 to entry: The mean air speed of vehicle surrounding flow is used for measurements at standstill.

Note 2 to entry: See normative Annex M for the position of the 6 measuring points.

3.24**mean air speed of interior flow**

arithmetic mean of the air speed measured at 6 points inside the vehicle at the distance of 0,1 m from the wall of the vehicle

Note 1 to entry: See normative Annex M.

3.25**vehicle interior temperature**

T_{iv}

arithmetic mean of all interior temperatures of all different comfort zones of the vehicle measured at 1,1 m above the floor as specified in the procedure described in normative Annex K

3.26**vehicle interior absolute humidity**

X_{iv}

arithmetic mean of the absolute humidity calculated with the local relative humidity in all different comfort zones of the vehicle and corresponding temperature measured at 1,1 m above the floor as specified in normative Annex K

3.27**vehicle interior relative humidity** **RH_{iv}**

relative interior humidity calculated with the interior mean temperature (T_{iv}) and absolute interior humidity (x_{iv})

3.28**control settling time** **t_{cs}**

maximum allowed time for achieving stabilised condition after a change of T_{ic}

3.29**stabilised condition**

condition achieved when the difference between the maximum and the minimum values of T_{im} is less than or equal to the defined limits

Note 1 to entry: Refer to 10.1.1.1.

3.30**single result** **X_{ijk}**

value measured during evaluation period which gives the worst single conformity level, in a single measuring point k or the value calculated over all single measuring points from a group k related to one specific T_{im} , in a single test i, for a single comfort parameter j, considered without regarding measuring tolerances

3.31**single conformity level** **Y_{ijk}**

conformity level for one comfort parameter j, in one specific test i, at one measuring point k or group of measuring points k, in relation to the corresponding quality limits q_1 and q_2

3.32**Comfort Level****CL**

index used to estimate the comfort of a vehicle

Note 1 to entry: Refer to Annex O for the calculation of this index.

4 Parameter selection

Table A.1 shall be completed to define all parameters needed to apply this document.

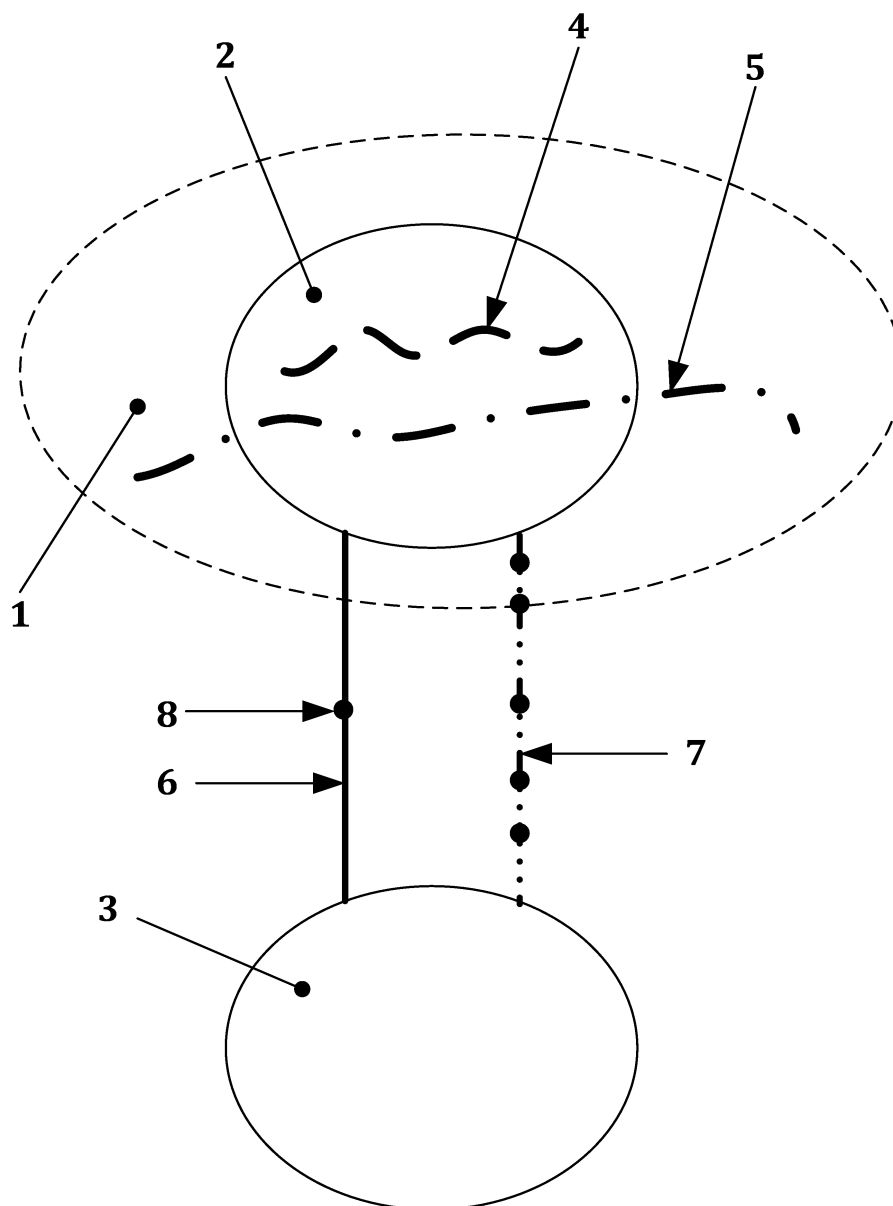
5 Vehicle categories

The contractual specification shall detail the operational scenario and vehicle category (refer to normative Annex A).

For guidance, the criteria to classify a vehicle for thermal comfort are given in Figure 3 and in Table 3. The limits of relevant comfort parameters vary with the applicable category.

- Urban (category U): Vehicles which operate inside the city (e.g. tram, metro).
- Suburban (category S): Vehicles which operate inside and in the surrounding of the city.

- Regional (category R): Vehicles which operate between cities with intermediate stops.
- Main line: Vehicles which operate between cities usually with a limited number of intermediate stops.



Key

- | | |
|---|-----------|
| 1 | Suburbs |
| 2 | City 1 |
| 3 | City 2 |
| 4 | Urban |
| 5 | Suburban |
| 6 | Main Line |
| 7 | Regional |
| 8 | Stops |

Figure 3 — Typical operating areas of different vehicle categories

Table 3 — Vehicle categories for passenger area

Typical values	Urban	Suburban	Regional	Main Line
Standard	EN 14750 Category U	EN 14750 Category S	EN 14750 Category R	EN 13129 [3]
Time between stops	< 3min	< 10min	5 – 30min	> 30min
Design passenger load	all seats occupied (excluding tip-up seats and wheelchairs) + 2p/m ²	all seats occupied (excluding tip-up seats and wheelchairs) + 2p/m ²	all seats occupied including tip- up seats and wheelchairs	all seats occupied, including tip- up seats and wheelchairs
Probability of removing clothing to suit thermal conditions	Low	Low	Medium	High

If the vehicle's operation is foreseen to be in more than one category, it is recommended to select the most appropriate vehicle category for thermal comfort.

The ability to achieve thermal comfort is influenced by the type of vehicle. It should be recognized that it may not be practicable to take a level of thermal comfort from one vehicle category and apply it to a different vehicle category. For example, it would unlikely be practicable to provide a main line vehicle level of thermal comfort within a metro vehicle.

6 Comfort parameters

Thermal comfort is assessed based on the following interior climate parameters:

- air temperature,
- air speed,
- relative humidity,
- surface temperatures,

as a function of thermal exchange between the interior climate and a seated or standing person dressed normally in accordance with Figure E.1 and as a function of the exterior climatic conditions which have an indirect effect.

The evaluation of the comfort parameters shall be done by quality limits q_1 and q_2 .

The minimum comfort level for each single test and for each car to be applied should be defined in the contractual specification. In the absence of such a definition, 85 % shall be reached at least.

NOTE 1 q_1 describes the targets for the comfort parameters to reach the thermal comfort and q_2 describes the maximum acceptable limits for the comfort parameters.

NOTE 2 The quality limits (normal or extended) are defined in Clause 10 as a function of the mean exterior temperature (T_{em}) in accordance with Table 4 and Table 5.

NOTE 3 Refer to Annex O for the details of the calculation of the comfort level.

7 Exterior conditions

7.1 Generalities

A climatic zone for winter and a climatic zone for summer shall be selected from Table F.1 (design conditions for winter) and Table F.3 (design conditions for summer). The selection should be based on local climatic conditions in which the system operates and should be specified in the contractual specification.

NOTE 1 To select the appropriate climatic zone, also refer to local climate databases.

The most appropriate climatic zone should be selected to avoid the oversizing of the HVAC system.

For tunnel operation (absence of sun load) the mean exterior temperature and the corresponding relative exterior humidity shall be indicated in the contractual specification.

NOTE 2 Generally the mean exterior temperature selected for tunnel operation corresponds to the maximum and minimum temperature observed in the tunnel.

The extreme exterior conditions for winter (Table F.2) shall correspond with the climatic zone selected from Table F.1.

The extreme exterior conditions for summer (Table F.4) and operational limits for summer (Table F.5) shall correspond with the climatic zone selected from Table F.3.

The thermal impact of the vehicle or / and of the infrastructures on the HVAC system shall be considered.

The thermal impact of the HVAC system on other equipment of the vehicle shall be considered.

7.2 Mean exterior temperature range with comfort criteria

The comfort parameters shall be satisfied within the range of exterior conditions of the selected climatic zones considering the limits of performance defined in Clause 8.

The normal range represents the most commonly occurring range of mean exterior temperature and therefore is highly important for the quality of comfort.

The extended range is valid for more severe exterior conditions that appear not so frequently, where a slight decrease of thermal comfort is acceptable.

Table 4 — Mean exterior temperature range for winter

Local Winter (LW) Zone	Normal range [°C]	Extended range [°C]
LW.1	$T_{em} \geq 5$	$0 \leq T_{em} < 5$
LW.2	$T_{em} \geq 0$	$-10 \leq T_{em} < 0$
LW.3	$T_{em} \geq -10$	$-20 \leq T_{em} < -10$
LW.4	$T_{em} \geq -15$	$-30 \leq T_{em} < -15$
LW.5	$T_{em} \geq -20$	$-40 \leq T_{em} < -20$

Table 5 — Mean exterior temperature range for summer

Local Summer (LS) Zone	Normal range [°C]	Extended range [°C]
LS.1	$T_{em} \leq 35$	$35 < T_{em} \leq 40$
LS.2	$T_{em} \leq 28$	$28 < T_{em} \leq 35$
LS.3	$T_{em} \leq 26$	$26 < T_{em} \leq 32$
LS.4	$T_{em} \leq 22$	$22 < T_{em} \leq 28$

7.3 Mean exterior temperature range with functional criteria

Down to the temperature given in Table F.2 the HVAC system shall be able to operate at the same functional status without active reduction of the capacity as for the design point in heating or to provide the same heating capacity as needed for the design point in heating.

NOTE 1 The interior conditions as defined in Clause 10 do not need to be complied with during these extreme conditions.

The HVAC system shall be able to continue to operate at least at the same functional status without active reduction of the capacity (refer to note 2) as for the design point in cooling up to the conditions given in Table F.4.

The HVAC system shall also continue to operate in at least reduced cooling mode up to the conditions given in Table F.5.

NOTE 2 Active reduction of the capacity could be for example usage of hot gas by-pass, power supply frequency reduction, reduction of the supply airflow.

It is allowed to increase the supply airflow or the condenser airflow under these conditions.

8 Performance of the heating and cooling installations

8.1 Design passenger load

For category R (see Clause 5), this passenger load is corresponding to all seats occupied including tip-up seats and wheelchairs.

For categories S and U (see Clause 5), this passenger load is corresponding to all seats occupied (excluding tip-up seats and wheelchairs) and 2 passengers/m² for standing areas.

8.2 Heating

At the mean exterior temperature for the climatic zone (Table F.1), at the maximum vehicle operational speed, without solar irradiation and with the most challenging combination of occupation and corresponding fresh air flow (see normative Annex G) for the heating capacity, the mean vehicle interior temperature (T_{iv}) in the comfort envelope shall be at least +18 °C for category R vehicles, +15 °C for category S vehicles and +10 °C for category U vehicles.

If any other conditions are indicated in normative Annex A (e.g. tunnel), it shall also be considered for the sizing and testing of the air conditioning installation.

8.3 Pre-heating

The pre-heating conditions and performance should be defined in the contractual specification.

Pre-heating conditions and performance are: maximum available electrical power at nominal voltage, mean exterior temperature, a mean interior temperature at starting, mean interior temperature to be achieved within the maximum pre-heating time (time begins when the vehicle is switched on). It is recommended to not exceed the heating capacity defined in 8.2.

In the absence of any of the above specifications, the pre-heating time depends on the performance defined in 8.2. In this case it is recommended to use a T_{im} of $T_{ic} - 2$ K to stop the pre-heating. If the system is not able to reach this interior temperature, the pre-heating test is stopped when the mean interior temperature does not increase more than 0,5 K within 30 min.

8.4 Cooling

At the mean exterior temperature for the climatic zone (Table F.3), including solar irradiation, with vehicle at standstill, with all doors and windows closed, for design passenger load (refer to definition 3.13 and 8.1) and corresponding fresh air flow (see normative Annex G), the mean vehicle interior temperature (T_{iv}) shall be less than or equal to the values in Table 6.

The vehicle relative interior humidity (RH_{iv}), corresponding to the temperature T_{iv} , shall be less or equal to the corresponding value of the curve q_1 defined in Figure D.1.

Table 6 — Maximum mean vehicle interior temperature at the design conditions

LS Zone	Category R	Category S	Category U
LS.1	+27 °C	+30 °C	+32 °C
LS.2	+27 °C	+30 °C	+32 °C
LS.3	+26 °C	+28 °C	+31 °C
LS.4	+25 °C	+26 °C	+29 °C

If any other conditions are indicated in normative Annex A, (e.g. tunnel), it shall also be considered for the sizing and testing of the air conditioning installation.

8.5 Pre-cooling

The pre-cooling conditions and performance should be defined in the contractual specification.

Pre-cooling conditions and performance are: Procedure for starting pre-cooling, maximum available electrical power at nominal voltage, mean exterior temperature and mean interior temperature to be achieved within the maximum pre-cooling time (time begins when the vehicle is switched on). It is recommended to not exceed the cooling capacity defined in 8.4.

In the absence of any of the above specifications, the pre-cooling time depends on the performance defined in 8.4. In this case it is recommended to use a T_{im} of $T_{ic} + 2$ K to stop the pre-cooling. If the system is not able to reach this interior temperature, the pre-cooling test is stopped when the mean interior temperature doesn't decrease more than 0,5 K within 30 min.

8.6 Stand by operation

If stand by operation is required, the requirements and the temperature range shall be detailed in the contractual specifications.

In absence of any indication regarding the stand by operation and performance in the contractual specification, the system shall maintain T_{im} above +3 °C.

During summer conditions it is recommended to use free cooling instead of the refrigerant circuit.

As a recommendation for category R, the system should be able to maintain T_{im} lower 30 °C in summer design conditions.

9 Control

9.1 General

Each vehicle shall be fitted with a regulation system which shall enable the comfort parameters defined in this document to be achieved.

9.2 Interior temperature setpoint (T_{ic})

The contractual specification should define a regulation curve for the interior temperature setpoint ($T_{ic,0}$), the maximal range of the offset of T_{ic} ($T_{ic,Off}$) and its increment. The interior temperature setpoint is given by Formula (6):

$$T_{ic} = T_{ic,0} + T_{ic,Off} \quad (6)$$

NOTE 1 For example the $T_{ic,Off}$ could be ± 2 K and the increment could be 0,5 K.

In the absence of such definition, the relevant curve shown in Figure B.1 and a $T_{ic,Off}$ of 0 K shall be adopted.

The mean interior temperature shall follow this regulation curve within the limits of capacity defined in Clause 8. Outside these limits temperature deviation is allowed.

NOTE 2 With the capacity determined according to this document, the HVAC system is not always able to provide a mean interior temperature (T_{im}) that reaches the interior temperature setpoint (T_{ic}).

9.3 Interior temperature setpoint (T_{ic}) for vehicles without cooling

The mean interior temperature shall meet interior temperature setpoint (T_{ic}) mentioned in 9.2 as long as the exterior conditions and / or internal loads enable this interior temperature to be achieved.

10 Comfort condition requirements

10.1 Requirements for comfort zone

10.1.1 Quality regulation for steady-state tests

10.1.1.1 Range of the mean interior temperature (T_{im}) with the respect to the interior temperature setpoint (T_{ic}) for steady-state tests (ΔT_i)

Within the performance limits defined in 8.2 and 8.4, the difference ΔT_i between the mean interior temperature (T_{im}) and interior temperature setpoint (T_{ic}) shall remain within the range of $\pm q_i$ (refer to key 4 of Figure 9). The values of q_i are defined in Table 7.

In case T_{im} is not reaching T_{ic} due to the performance limits defined in 8.2 and 8.4, the weighting factor used for this comfort parameter is set to 0 (zero) in the calculation of comfort level (refer to normative Annex O).

Table 7 — Quality limits for the range of the mean interior temperature with the respect of the interior temperature setpoint for steady-state tests

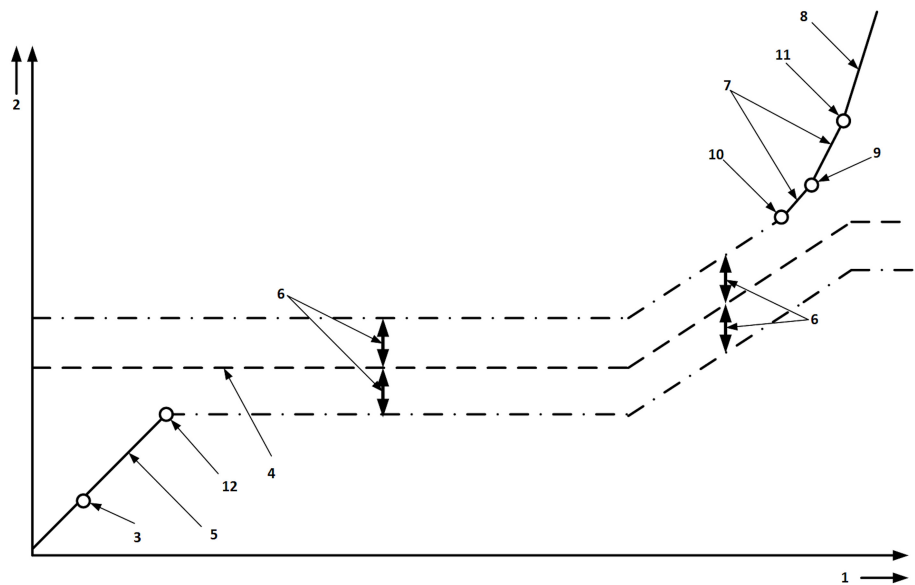
Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
ΔT_i [K]	q_1	1,3	1,3	1,7	1,7	1,7	1,7
	q_2	1,7	1,9	2,2	2,6	2,2	2,6

NOTE The interior temperature setpoint only defines the interior temperature that the system tries to reach but does not define the heating or cooling capacity. Capacity is determined based on the design points in 8.2 for heating and 8.4 for cooling. The difference between the mean interior temperature and the interior temperature setpoint may be greater than the value specified in 10.1.1.1. This is caused by the limitation of the heating or cooling capacity. If conditions (e.g. solar radiation, number of passengers, humidity, vehicle speed...) are less demanding than the design conditions, the interior temperatures correspond better with the regulation curve. For example, in heating mode this is the case if the sun shines or if there are passengers in the vehicle; in cooling mode it is the case if the solar radiation is low or if the vehicle is not fully occupied.

Figure 4 represents the expected range of the interior temperature, which can be achieved.

In case of $T_{ic,Off}$ change, the points 3 and 9, the curves 5 and 7 of Figure 4 do not change. The other lines will follow $T_{ic,Off}$.

The curve 7 represents the maximum interior temperature reached with the HVAC system in full cooling capacity.



- Key**
- 1 Mean exterior temperature T_{em} [°C]
 - 2 Temperature limits for T_{im} , T_{ic} , T_{iv} [°C]
 - 3 Design point for heating (refer to 8.2)
 - 4 Interior temperature setpoint T_{ic} [°C]
 - 5 T_{im} according to performance limits in chapter 8.2 [°C]
 - 6 Maximum allowed deviation of T_{im} with respect to T_{ic} [K]
 - 7 T_{im} according to performance limits in chapter 8.4 [°C]
 - 8 Fixed upper limit for the accepted T_{im} with HVAC system in reduced cooling mode [°C]
 - 9 Design point for cooling (refer to 8.4) [°C]
 - 10 Maximum of mean exterior temperature on which HVAC system is able to maintain T_{im} within the maximum allowed deviation of T_{im} [°C]
 - 11 Maximum of mean exterior temperature on which HVAC system is able to operate in full cooling mode [°C]
 - 12 Minimum of mean exterior temperature on which HVAC system is able to maintain T_{im} within the maximum allowed deviation of T_{im} [°C]

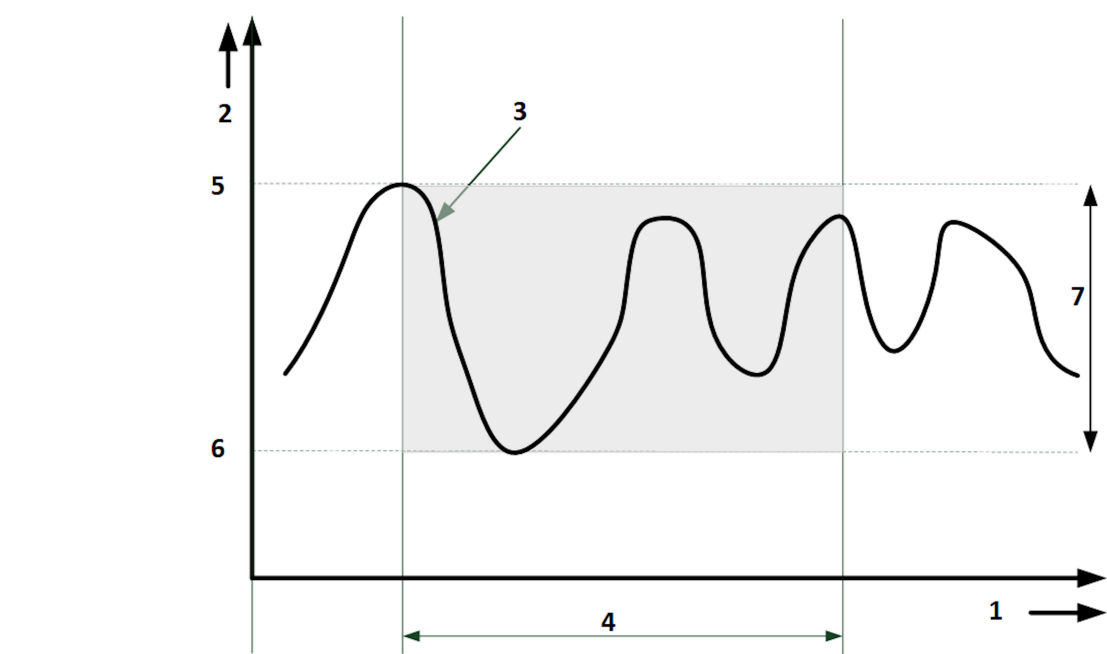
Figure 4 — Expected range of the interior temperature

10.1.1.2 Range of variation of mean interior temperature (T_{im}) for steady-state test (ΔT_{i10})

Within every single time window of 10 min during the time of 30 min of comfort parameter evaluation (refer to key 4 of Figure 9), the difference between the maximum and the minimum values of T_{im} shall be less than or equal to the values q_i defined in Table 8. See Figure 5 for explanation.

Table 8 — Quality limits for the range of variation of mean interior temperature for steady-state tests

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
ΔT_{i10} [K]	q_1	1,7	1,7	2,6	2,6	2,6	2,6
	q_2	2,2	2,6	3,3	3,8	3,3	3,8



- Key**
- 1 Time [min]
 - 2 Temperature [°C]
 - 3 Mean interior temperature (T_{im}) [°C]
 - 4 Time window of 10 min [min]
 - 5 T_{im} (max) maximum of T_{im} in time window (key 4) [°C]
 - 6 T_{im} (min) minimum of T_{im} in time window (key 4) [°C]
 - 7 Range of variation of mean interior temperature (T_{im}) (ΔT_{i10}) [K]

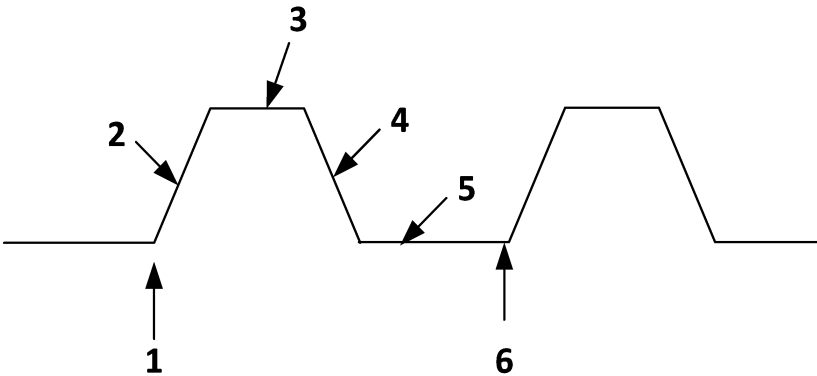
Figure 5 — Stabilized condition

10.1.2 Quality of regulation for regulation tests

10.1.2.1 Door cycling sequence

Table 9 — Door opening/closing cycle

Time interval	Category R	Category S	Category U
Doors closed and locked (refer to key 5 of Figure 6)	10 min	5 min	2 min
Doors fully open (refer to key 3 of Figure 6)	40 s	30 s	20 s



- Key**
- 1 Start of the cycle
 - 2 Opening of the doors
 - 3 Doors fully open
 - 4 Closing of the doors
 - 5 Doors closed and locked
 - 6 Evaluation point – End of the cycle

Figure 6 — Door cycle

Prior to the door cycle test, the time duration 2 and 4 of the Figure 6 shall be measured.

10.1.2.2 Changing interior temperature setpoint (T_{ic})

When changing the interior temperature setpoint (T_{ic}) by $T_{ic,Off}$, after the control settling time of t_{cs} (refer to Formula (7)), T_{im} shall be according to 10.1.1.1 and Formula (8). See Figure 7 for explanation.

$$t_{cs} = (T_{ic,Off} \times 15) + 5 \quad (7)$$

Where

t_{cs} Control settling time [min];

$T_{ic,Off}$ Variation of the interior temperature setpoint (refer to Formula (8)) [K].

$$\left| T_{ic,Off} - (T_{im}(1) - T_{im}(0)) \right| \leq |q_i| \quad (8)$$

Where

$T_{ic,Off}$ Variation of the interior temperature setpoint [K];

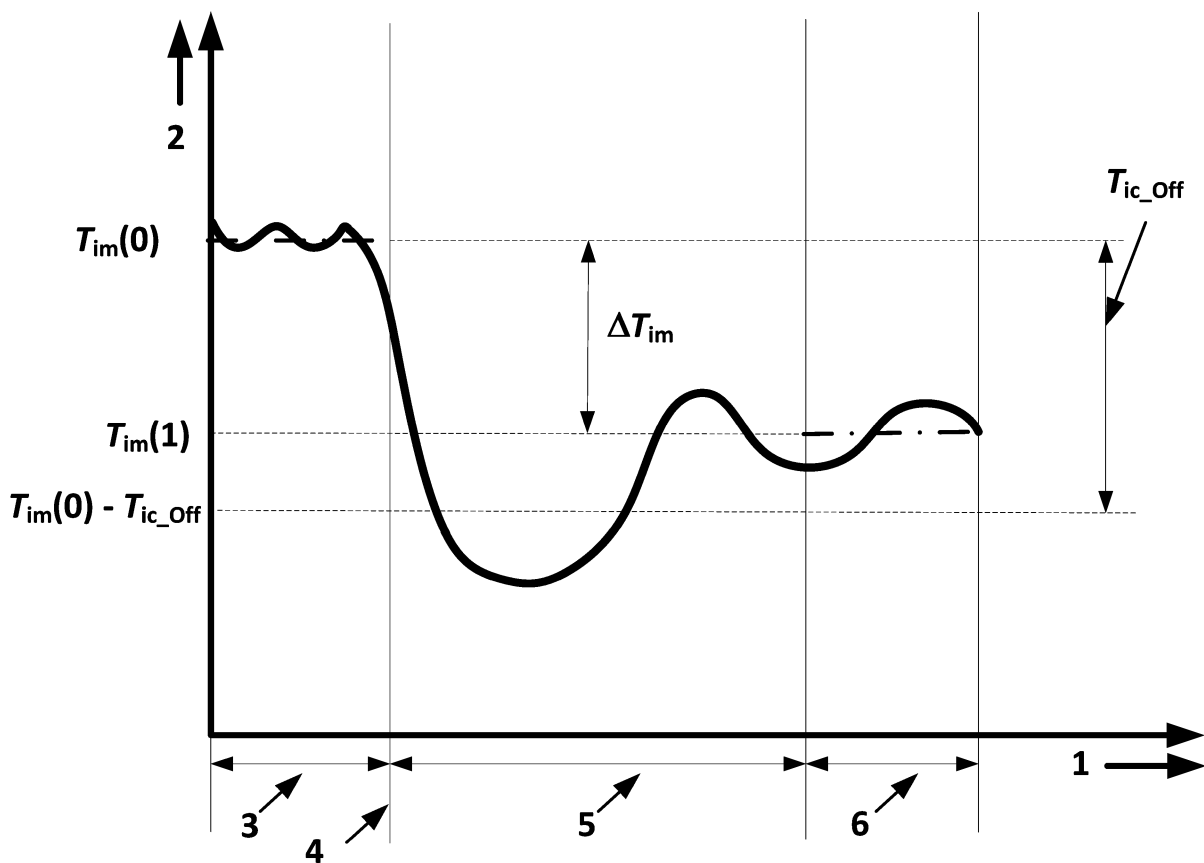
$T_{im}(0)$ Average of T_{im} over the last 10 min of the previous single test (refer to key 3 of Figure 7) [°C];

$T_{im}(1)$ Average of T_{im} over 10 min, right after t_{cs} (refer to key 6 of Figure 7) [°C];

q_i Quality limit with the values defined in Table 10.

Table 10 — Quality limits for set point change

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
Set point change $\Delta T_{ic,ch}$ [K]	q_1	0,15	NA	0,15	NA	0,15	NA
	q_2	0,5	NA	0,5	NA	0,5	NA



Key	
1	Time [min]
2	Temperature [°C]
3	10 min [min]
4	Change of T_{ic}
5	t_{cs} [min]
6	10 min for the evaluation [min]

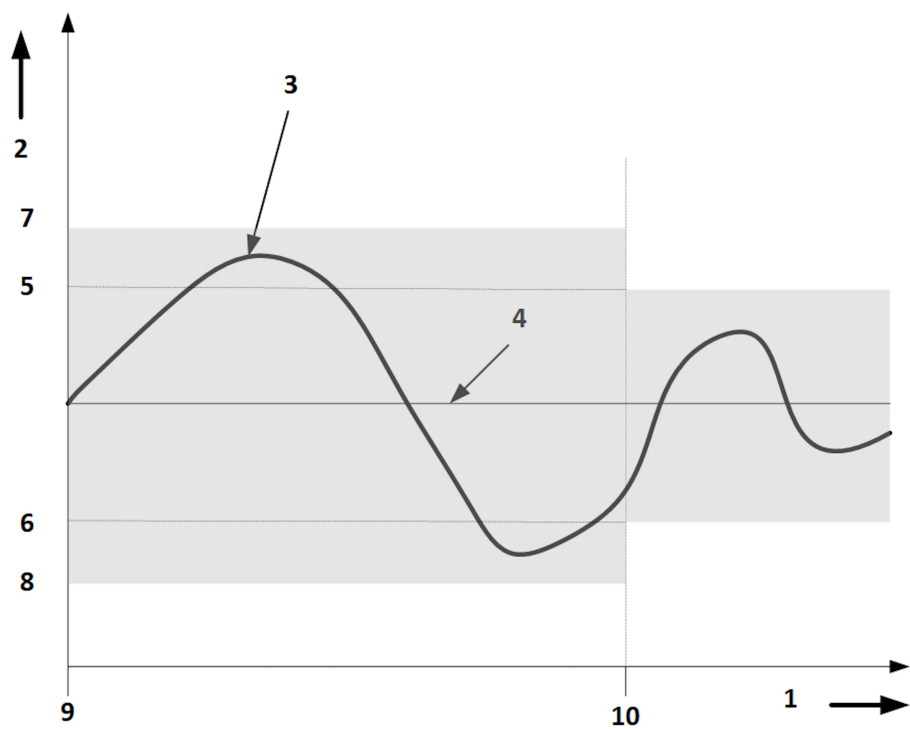
Figure 7 — Changing the interior temperature setpoint (T_{ic})

10.1.2.3 Changing test parameters

During the regulation test, the deviation (ΔT_i) of mean interior temperature (T_{im}) with respect to the interior temperature setpoint (T_{ic}) shall be compliant with the criteria of 10.1.1.1 (normal limit).

NOTE The test parameters could be T_{em} , RH_{em} , Solar irradiation, occupation load.

An additional deviation of 1 K (on q_1 and q_2) is allowed for a period of 15 min for category U, 25 min for category S and 35 min for category R (extended limit). This period starts when the test parameters are changed at the beginning of each test step. See Figure 8 for explanation.



Key

- | | |
|----|---|
| 1 | Time [min] |
| 2 | Temperature [°C] |
| 3 | Mean interior temperature (T_{im}) [°C] |
| 4 | Interior temperature setpoint (T_{ic}) [°C] |
| 5 | Normal upper limit for T_{im} [°C] |
| 6 | Normal lower limit for T_{im} [°C] |
| 7 | Extended upper limit for T_{im} [°C] |
| 8 | Extended lower limit for T_{im} [°C] |
| 9 | Start of the deviation period [min] |
| 10 | End of the deviation period [min] |

Figure 8 — Authorized temperature during changing test parameters

During the last 10 min of a test step of the regulation test, the mean interior temperature (T_{im}) with respect to the interior temperature setpoint (T_{ic}) shall be compliant with the criteria of 10.1.1.1.

10.1.3 Horizontal range of the extreme interior air temperatures (ΔT_H)

This range shall not be greater than the values defined in Table 11.

Table 11 — Quality limits for horizontal range of the extreme interior air temperatures

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
ΔT_H [K]	q_1	3,0	3,0	3,4	3,4	6,8	6,8
	q_2	3,9	4,5	4,4	5,1	8,8	10,2

10.1.4 Vertical range of the extreme interior air temperatures (ΔT_V)

This range shall not be greater than the values defined in Table 12.

Table 12 — Quality limits for vertical range of the extreme interior air temperatures

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
ΔT_V [K]	q_1	3,4	3,4	5,1	5,1	6,8	6,8
	q_2	4,4	6,0	5,1	8,0	8,8	10,2

NOTE For category R, q_2 is extended to 6 K for normal range and 8 K for extended range if the foot is the warmest point.

10.1.5 Temperatures of the surfaces surrounding the comfort zone

The temperatures of the surfaces shall be in accordance with Table 13. For surface temperature of the heater, refer to Note 2.

Table 13 — Surface temperature limits (T_S)

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
Minimum Surface temperature for walls $T_{im} - T_{s_Wal} = < q_i$ [K]	q_1	9	9	9	9	9	9
	q_2	11	13	11	13	11	13

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
Maximum surface temperature of wall $T_{S_Wal} - T_{ic} = < q_i$ [K]	q_1	7	7	7	7	10	10
	q_2	9	10	9	10	13	15
Minimum Floor surface temperature $T_{im} - T_{S_Fl} = < q_i$ [K]	q_1	9	9	9	9	10	NA
	q_2	11	13	11	13	13	NA
Maximum floor surface temperature $T_{S_Fl} - T_{ic} = < q_i$ [K] ^a	q_1	7	7	8	8	10	10
	q_2	9	10	10	11	13	15
Minimum interior surface temperature of window panes $T_{im} - T_{S_Win_pa} < q_i$ [K] ^b	q_1	10	10	NA	NA	NA	NA
	q_2	13	15	NA	NA	NA	NA
Maximum interior surface temperature of window panes $T_{S_Win_pa} - T_{ic} = < q_i$ [K] ^b	q_1	13	13	NA	NA	NA	NA
	q_2	18	20	NA	NA	NA	NA

Parameters	Quality limits	Category R		Category S		Category U	
		Normal Range	Extended Range	Normal Range	Extended Range	Normal Range	Extended Range
Maximum interior surface temperature of outside access door $T_{S_Do} - T_{ic} = < q_i$ [K] ^c	q_1	13	13	NA	NA	NA	NA
	q_2	18	20	NA	NA	NA	NA
Maximum seat surface temperature T_{S_Seat} - $T_{ic} = < q_i$ [K] ^d	q_1	10	10	11	11	12	12
	q_2	13	15	14	16	15	18
^a The reference is T_{ic} in order to use the maximum potential of the heating floor even at the design point where T_{im} is authorized to not reach T_{ic}. ^b For categories S and U there is no requirement as usually single glass panes are used. ^c For categories S and U there is no requirement as usually doors without insulation are used. ^d One representative seat temperature is measured only in heating mode if a heater is present close to the seat.							

NOTE 1 The value used for T_{im} in the previous table is relative to the comfort zone or local annex in which the measuring point is installed.

NOTE 2 This document does not cover the requirements linked to the surface temperature of the heater accessible by passengers. In this case, refer to EN ISO 13732-1:2008.

The requirement for the windows of the doors indicated in Table 13 shall respect the criteria of the doors.

NOTE 3 The requirements for the windows panes are not applicable for the windows of the doors.

10.1.6 Relative humidity for air-conditioned vehicle (RH_{im})

Only if humidity control is requested and within the limitations of the equipment performance defined in Clause 9, the maximum relative interior humidity in the comfort zone shall be according to normative Annex D and Figure D.1.

10.1.7 Air speed (AS)

The air speed in the comfort zone shall be equal to or less than the values given in normative Annex C (refer to Figure C.1 and Table C.1 for the acceptable values). The assessment shall be done in function of corresponding local temperature.

NOTE The local temperature is the temperature measured at the same position than the airspeed.

10.2 Requirements for local annexes (T_{Loc})

The vestibule temperature (T_{ves}) and the temperature in the aisle without permanent seat (T_{Ais}) shall be measured at the height of 1,7 m above the geometric centre of the floor. In addition, the temperature shall always be above + 3 °C at 0,1 m above the vestibule floor.

The temperature for toilet compartment (WC) (T_{WC}), baby change area (T_{Baby}) and other local annexes (T_{LA}) shall be measured at the height of 1,1 m above the geometric centre of the floor.

The temperature for multi-purposes area (T_{MPA}) shall be measured at the heights of 1,1 m and 1,7 m above the geometric centre of the floor.

The temperatures of the local annexes shall be within the limits defined in Table 14. Refer to Figure K.5 for the location of these different temperature sensors.

Table 14 — Temperatures in the local annexes

Parameters	Permissible temperature [°C]	
	Normal Range	Extended Range
$T_{Ves}, T_{WC}, T_{Ais}, T_{LA}, T_{MPA}$	$T_{iv} \pm 5$	$T_{iv} \pm 6$
T_{Baby}	$T_{iv} - 2 < T_{im} < T_{iv} + 5$	$T_{iv} - 3 < T_{im} < T_{iv} + 6$

10.3 Air quantities and quality

10.3.1 Outside air or fresh air

The total volume of fresh air added by forced ventilation to the comfort envelope shall be in accordance with the values defined in normative Annex G.

10.3.2 Smoking areas

In the case of composite vehicles (smoking, non-smoking), the HVAC system shall be designed to prevent the transfer of smoke from a smoking zone to a non-smoking zone.

10.3.3 Toilet

The vehicle HVAC system shall be designed to prevent the transfer of odours from toilet compartment (WC) into any other areas.

10.3.4 Particle air filtration

The mixed air shall be filtered. In the absence of filter class in the specification, the recommended filter class, is coarse 60 % or higher for category R and coarse 40 % or higher for categories S and U according to EN ISO 16890-1:2016.

NOTE If the system filters the fresh air and return air, or fresh air and mixed air or only mixed air, the mixed air is considered to be filtered.

11 Complementary requirements

11.1 Heat transfer coefficient (k)

11.1.1 General

It is recommended to measure the coefficient k during the climatic tests.

11.1.2 Standstill coefficient k of the vehicle

The standstill coefficient k of the vehicle shall be considered at 5 km/h (average air speed measured at the outside points defined in Figure M.3). The standstill coefficient k shall be less than or at least equal to the corresponding value indicated in Table 15.

Table 15 — Standstill coefficient k for the vehicle at 5 km/h

LW Zone	Category R - Single Deck [W/(m ² .K)]	Category R - Double Deck [W/(m ² .K)]	Category S - Single Deck [W/(m ² .K)]	Category S - Double Deck [W/(m ² .K)]	Category U [W/(m ² .K)]
LW.1	2,2	2,5	2,5	2,8	3,5
LW.2	2,2	2,5	2,5	2,8	3,5
LW.3	1,8	2,2	2,2	2,6	3,0
LW.4	1,6	2,0	2,0	2,3	2,5
LW.5	1,6	2,0	2,0	2,3	2,5

11.2 Condensation

No water due to the effect of condensation shall appear on ceilings in comfort envelope and local annexes. A visual inspection shall be performed to assess this requirement.

It is recommended to ensure a minimum supply air temperature of 12 °C at the air diffusion outlets.

11.3 Solar factor (g) of the windows

It is recommended for vehicles used mainly for surface operation to use windows with a low solar factor (as defined in EN 410:2011 [2]) in order to minimize the cooling capacity and improve passenger comfort in summer conditions.

11.4 Sealing against water and snow

Precautions on HVAC system should be taken to avoid the infiltration and retention of water from condensation, rain and washing plants, as well as snow.

12 Validation

12.1 General

The comfort criteria are relevant for normal passenger service. As it is difficult to show the fulfilment of all the comfort criteria in on-track service, the test conditions described in this document cover some typical situations.

12.2 Test levels

Three test levels are detailed in this document:

- TL1 is the simplified test level that gives basic information about the functionality of the system and about fulfilment of comfort parameters on limited range of exterior conditions. This test does not give a direct mean of proof of the heating and cooling performances defined in 8.2 and 8.4. The results of the tests could be used to extrapolate to the design points. These tests can be done in a workshop or at an outside location;

- TL2 is the test level to verify the comfort parameters and the performances of the system without the influence of vehicle speed. These tests shall be performed in a climatic chamber;
- TL3 is the full test level to verify the comfort parameters and the performance of the system. These tests shall be performed in a climatic wind tunnel.

In absence of external devices to simulate sun, it can be simulated by internal devices.

The test classification shall be detailed in the contractual specification.

In the absence of any specified contractual detail, TL2 shall apply. If not stated otherwise, the following requirements apply to TL1, TL2 and TL3.

It is recommended to perform additional dynamic tests on track during different seasons to verify the behaviour of the HVAC system.

12.3 Selection of tested vehicles

The configuration of vehicles for the categories Regional, Suburban and Urban are quite different so this standard cannot cover all these cases. For the tests representative vehicles shall be selected. The selection of tested vehicles shall consider different parameters like layout, duct and air-conditioning system arrangement. The number of tested vehicles shall be indicated in normative Annex A.

12.4 Assessment of comfort criteria based on simulation

12.4.1 Introduction

To validate the thermal comfort of a vehicle, the simulations could be used in some cases:

- On one dedicated project there are more types of vehicles than the number of vehicles tested in climatic chamber. The thermal comfort of the non-tested type of vehicles could be validated by simulation if the differences between the two types of vehicle are classified as minor (refer to informative Annex P for some examples of minor / major gaps);
- A platform vehicle is validated according to TL2 / TL3 program, and the validation of a second project linked to the same platform could be performed by using simulation;
- A vehicle has been tested in climatic chamber with some non-conformities. The minor modifications could be validated by simulation;
- The project consists of a modernisation or refurbishment of already validated vehicles.

If simulation wants to be used to validate the thermal comfort of one vehicle, the following process shall be used:

- A preliminary comparative simulation between the two configurations (before and after change) shall be performed;
- An agreement between different stakeholders shall be found to classify the changes (insignificant, minor or major) and the limits of simulations. The consequences of this classification are:
 - In case of insignificant changes, the preliminary simulation is enough to validate the change;
 - In case of minor changes, the detailed simulation shall be performed;
 - In case of major changes, the validation of thermal comfort shall be done in climatic chamber.

NOTE Table P.1 could help for the classification of the changes.

- An agreement between different stakeholders shall be found to define the necessary simulated cases selected in normative Annex H and the tool to perform these simulations.

If simulation is used, the following methodology shall be used:

- A similar vehicle (reference case) was previously tested according to level TL2 or TL3;
- The selected tests on the different type of vehicles of this reference vehicle are simulated;
- The comparison between the tests and the simulation permit to calculate a handicap (refer to normative Annex Q);
- This handicap is used for the evaluation of the comfort in the vehicle validated by simulation. The simulation models used for the reference case and the simulation of vehicle to validate shall be equivalent. To validate all comfort criteria, different tools and methods could be used;
- The tool and methods used for the two simulations (reference case and vehicle validated by simulation) shall be the same.

In case of reference case is validated according to previous version of this document, the simulation of this reference case shall be done accordingly to calculate the handicaps. These shall be used for the simulations of the vehicle validated by simulation based on this version of EN 14750.

12.4.2 Comparison between test and simulation of the reference case

The comparison report between the test and the simulation of the reference case shall include at the minimum the following information:

- Simulation Software: Description of numerical method, used software, description of numerical mesh;
- An analysis that demonstrates the simulation model is consistent with the physical properties of the railway vehicle (description, model simplifications) and the test setup (e.g.: temperature, humidity, solar irradiation, air speed, passenger load, internal load...);
- An analysis of the positions of the tests equipment (sensors, carpets, boilers, heaters,...) and simulation. A description of the mean to simulate sensible and latent heat load exhausted by passengers shall be added. The volume and power (sensible and latent) of the equipment used during the measurement to simulate the heat exhausted by passengers shall be documented in the test and simulation reports;
- For each post-processing point, it is possible to introduce a local volume or surface around the reference point to average the simulated values. The reference points are defined in the same location than the measuring points (refer to Annex K and Annex L). It is recommended to use a sphere for air measurement and circle for surface measurement with a maximum diameter of 50 mm ;
- An analysis of the geometry and thermal hypothesis of the simulation shall be performed and includes:
 - Detailed comparison of real geometry and simulation model;
 - A special focus on the details of duct system, air return, air exhaust and intake parts;

- Description thermal transport properties of the car body of the vehicle (especially to the outside, i.e. insulation, windows, external leakages...).

NOTE Different methods to assess the external leakages exist, such as, for example, using a smoke generator or creating an internal overpressure or by measuring the CO₂ concentration inside the vehicle.

- Comparative table between test and simulation of the reference case (refer to normative Annex Q).

12.4.3 Vehicle validated by simulation

The simulation report of the validated vehicle shall include at the minimum the following information:

- Description and classification of the changes or modifications between the reference cases and the vehicle validated by simulation;
- The completed tables of normative Annex Q;
- Description of the simulation model.

13 Preliminary verifications

To reduce the risk of failing the tests, it is recommended that preliminary tests are carried out to verify the electrical and electronic assemblies, the functional logic of the control system, the air tightness of the air distribution system, the water tightness of the vehicle and the thermal capacity of the air conditioning equipment. In case of TL2 or TL3 tests, it is further recommended to perform tests in climatic chamber or wind tunnel before proceeding to the normative tests.

14 Air movement tests

14.1 General remarks

The tests shall be carried out under the following conditions:

- vehicle at standstill and protected from bad weather;
- altitude < 1 000 m above sea level;
- exterior air speed (wind) between 0 km/h and 5 km/h;
- mean exterior temperature between + 15 °C and + 30 °C.

14.2 Air flow rates

The flow rates of outside air (fresh air) shall be measured in accordance with 16.5.

14.3 Visualization of the air flow direction

If appropriate, this can be shown by the movement of smoke between the two relative areas.

In particular, this visualization shall be made for composite vehicles (smoking/non-smoking), toilet compartment (WC) in order to verify that the HVAC system is well designed to avoid the propagation of odours.