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Railway applications — Heating, ventilation and air conditioning systems for rolling stock —

Part 2:
Thermal comfort

Applications ferroviaires — Systèmes de chauffage, ventilation et climatisation pour le matériel roulant —

Partie 2: Confort thermique

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Foreword

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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).

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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 269, *Railway applications*, Subcommittee SC 2, *Rolling Stock*.

A list of all parts in the ISO 19659 series can be found on the ISO website.

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

Thermal comfort is the condition that expresses satisfaction with the thermal environment. This is mostly reached if the heat generated by the human metabolism is allowed to dissipate in every part of the human body in order to maintain thermal equilibrium with the surroundings. Since the heat generated by the human metabolism is individual, the satisfaction with the thermal comfort condition is also individual.

The main factors that influence thermal comfort locally at every part of the human body are physical activity, clothing insulation, air temperature, mean radiant temperature, air velocity and relative humidity. A satisfying thermal equilibrium can be reached in various combinations of the mentioned factors. Therefore, it is not possible to specify an independent optimum of a single factor, like air temperature, mean radiant temperature, air velocity or relative humidity.

ISO 7730 presents methods for predicting the general thermal sensation and degree of thermal satisfaction of people exposed to moderate thermal environments in buildings.

The thermal comfort sensation in railway vehicles is in addition strongly affected by temporary factors.

Passengers enter the vehicle coming from an environment with a different thermal condition and with an individual physical activity level. Thermal comfort sensation is then temporary depending on the thermal equilibrium and comfort sensation generated in the environment where they are coming from. In hot weather conditions, passengers who travel just for some minutes in an urban train typically prefer lower temperatures and higher air velocities than passengers who travel for some hours in a long-distance train. Further, whether passengers adapt their clothing during their stay in the vehicle is of additional influence.

The thermal comfort which can be offered is also affected by temporary factors. The interaction of the vehicle with the environment influences the thermal condition in the occupied areas in a dynamic way. Door openings in train stations, rapidly changing outside weather conditions, rapidly changing degree of occupation cannot be balanced promptly by the installed HVAC system.

The mentioned combinations of air temperature, mean radiant temperature, air velocity and relative humidity are furthermore limited by the high grade of occupation, high air volume exchange rate, short distance between passenger and surrounding surfaces and other technical constraints of a railway vehicle.

This document takes into account these special conditions in railway vehicles. It deals with the influence of the exterior climatic condition on the dimensioning of the HVAC system, the air quality, and the measurement methods in order to achieve adequate thermal comfort. This document also considers specific areas in railway vehicles, such as sanitary rooms, entrance areas and galleries.

This document describes the parameters and requirements in general which should be taken into account when designing and testing an HVAC system for railway vehicles. This document also describes guidelines to specify conditions, performance values and the comfort parameter measurement methods, but does not specify detailed pass and fail criteria for comfort requirements or any other technical property of the railway vehicles.

These specifications are designed to be considered together with the national/regional standards, which take into account different preferences, local weather and operational conditions.

Railway applications — Heating, ventilation and air conditioning systems for rolling stock —

Part 2: Thermal comfort

1 Scope

This document specifies a general approach for achieving thermal comfort for passenger compartments or saloons of railway vehicles (single level or double-decker) such as main line, regional/suburban and urban vehicles used in public transportation services.

This document also describes guidelines to specify conditions, performance values and the comfort parameter measurement methods for compartments, saloons and local annexes.

This document does not apply to the thermal comfort of the cab driver.

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.

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

3 Terms and definitions

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

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

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

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

4 Category of passenger railway vehicles

4.1 General

For the needs of this document, passenger railway vehicles are categorized into three types that consider average passenger travel time and average time between station stops next to each other. The following subclauses, 4.2, 4.3 and 4.4, are helpful for choosing the category.

NOTE The ability to achieve thermal comfort is influenced by the type of train. It is not practicable to take a level of thermal comfort of one vehicle category and apply it to a different vehicle category. For example, it is generally not feasible to provide the higher level of thermal comfort of a main line train in an urban train.

4.2 Category 1 (e.g. main line, intercity, long-distance, high speed)

Passenger railway vehicles are typically used in long-distance transit services between major cities and/or regions of a country and sometimes across several countries. They have toilets and often have food service facilities, such as a dining car or a restaurant car. Passenger railway vehicles travelling overnight also sometimes have sleeping cars. Passenger coach interiors are typically fitted with comfortably spaced and configured seating and separated by interior doors from the vestibule. The average passenger travel time is typically more than 30 minutes and the average time between consecutive station stops is typically 15 to 30 minutes or more.

4.3 Category 2 (e.g. suburban, commuter, regional)

Passenger railway vehicles are typically used in medium-distance transit services between cities and suburban areas or between smaller communities along the line or at the outer rim of a suburban belt. Passenger coach interiors are normally equipped with high-density seating with proportionately limited space for standing passengers. The average passenger travel time is typically more than 20 minutes and the average time between consecutive station stops is typically 5 to 10 minutes.

4.4 Category 3 (e.g. urban, LRV, tram, metro/subway)

Passenger railway vehicles are typically used in high-density urban passenger transportation services. Passenger coach interiors are normally equipped with limited seating with a proportionately large space for standing passengers. The average passenger travel time is typically less than 20 minutes and the average time between consecutive station stops is typically 1 to 5 minutes.

5 Design conditions

5.1 General

Exterior/interior boundary conditions, under which the comfort parameters shall be achieved, shall be specified as the design conditions in the technical specification.

Since exterior/interior design conditions depend on local climatological conditions, this document does not give specific values for exterior/interior design conditions. It is recommended to use values taken from relevant national/regional standards, literature or existing meteorological data. In case such values are not available, this document provides recommended values that can be applied in general.

5.2 Exterior design conditions

5.2.1 Parameters

The values for the parameters — temperature and corresponding relative humidity, solar radiation, altitude, train speed — shall be specified based on actual conditions throughout the service route and should be described in the technical specification or the relevant national/regional standard.

In 5.2.2 to 5.2.5, recommendations are given that specify the exterior design conditions.

5.2.2 Temperature and corresponding relative humidity

Table 1 gives typical climatic design conditions for summer and Table 2 gives typical climatic design conditions for winter. For winter, relative humidity is not relevant and therefore, not considered. After extensive research, various climatic design conditions are collected, but not exhaustively. The collected conditions are grouped into 11 climatic conditions for summer and 7 climatic conditions for winter, covering most of the climatic design conditions worldwide.

The climatic design conditions for summer and winter can be selected from Table 1 and Table 2. Projects with particular local conditions could require the definition of a design point other than recommended in Table 1 and Table 2.

Table 1 — Typical climatic design conditions for summer

Climatic design condition	Exterior design temperature °C	Relative humidity %	Enthalpy (standard condition) kJ/kg	Relevant zone (example)	Relevant document (example)
TS1	28	45	55,3	North Europe	EN 13129 EN 14750
		(50)	(58,4)	(China)	(GB/T 33193.1)
TS2	32	50	70,5	Central Europe	—
TS3	33	69	89,7	Japan	JIS E 6603
				Malaysia Vietnam	—
TS4	35	50	80,8	Central Europe	EN 13129 EN 14750
TS5	35	60	90,2	Argentina Thailand Russia	—
				China	GB/T 33193.1
TS6	35	65	94,9	Brazil China Middle East	—
TS7	35	75	104,5	Brazil India Indonesia Singapore Thailand	—
TS8	40	40	88,3	South Europe	EN 13129 EN 14750
		(46)	(95,8)	(China)	(GB/T 33193.1)
TS9	40	60	113,4	Singapore Venezuela	—
TS10	45	10	60,6	Middle East	—
TS11	45	30	92,2	India USA	—

Table 2 — Typical climatic design conditions for winter

Climatic design condition	Exterior design temperature °C	Relevant zone (example)	Relevant document (example)
TW1	−40	China	GB/T 33193.1
		North Europe	EN 13129 EN 14750
		Russia	—
TW2	−30	USA	—

Table 2 *(continued)*

Climatic design condition	Exterior design temperature °C	Relevant zone (example)	Relevant document (example)
TW3	−25	China	GB/T 33193.1
TW4	−20	Argentina	—
		Central Europe	EN 13129 EN 14750
TW5	−10	China	GB/T 33193.1
		South Europe	EN 13129 EN 14750
TW6	0	Argentina Brazil	—
		Japan	JIS E 6603
TW7	5	Brazil India	—

NOTE 1 The "ASHRAE Handbook — Fundamentals" is a reference source of local climatological conditions, usable for selecting the appropriate design conditions.

NOTE 2 Annex A introduces exterior design temperature and corresponding relative humidity given in national/regional standards of Japan, China and Europe, and design conditions recommended in the ASHRAE Guideline.

5.2.3 Solar radiation

The solar load shall be specified for summer only. It could be taken from national/regional standards, literature or existing meteorological data.

The "ASHRAE Handbook — Fundamentals" recommends calculating the solar load under the condition of 21 July at 4:00 pm local standard time. This is because:

— July is typically the hottest month in the northern hemisphere, and

— 4:00 pm local standard time is typically the time of day when the combination of total solar irradiance and ambient temperature results in the greatest cooling gain.

If no values are available, a solar load of 700 W/m^2 at an angle of 30 degrees to the horizontal is recommended.

5.2.4 Altitude

Altitude throughout the service route shall be considered. If the difference in altitude between the testing location and the actual operating location is larger than 1 000 m, the reduction of cooling capacity shall be taken into account.

5.2.5 Train speed

The maximum operational train speed shall be considered for winter condition. Zero train speed shall be considered for summer condition.

5.3 Extreme exterior conditions

Extreme conditions should be specified in the technical specification to ensure the function of the system and to prevent an oversized HVAC system design. If not specified in the technical specification or national/regional standard, the following recommended values apply.

The function of the HVAC system installation shall be maintained up to extreme exterior temperatures: 5 K below the exterior design temperature for winter and 5 K above the exterior design temperature for summer. However, it should be recognized that thermal comfort parameters may not be achieved.

5.4 Interior design conditions

5.4.1 Internal heat gains

The following internal heat gains shall be taken into account during summer:

— electrical cubicles;

— electrical devices;

— catering equipment;

— number of persons (passengers/train staff; heat load per person);

— fresh air volume flow rate.

For winter, only the fresh air volume flow rate shall be considered, except in cases where national standards or technical specifications allow consideration of the heat emission of persons and related fresh air volume flow rate. In such cases, the most critical operational case shall be considered for the design (occupation and related fresh air volume flow rate).

The passenger heat load shall be assessed on the basis of an even distribution under a given number of passengers (e.g. over the seats/standing).

These conditions shall be specified in the technical specification.

5.4.2 Temperature and corresponding relative humidity

The values of Table 3 and Table 4 for the selected climatic design conditions according to 5.2.2, are given as recommendations to specify temperature and corresponding relative humidity. For winter condition, relative humidity is not relevant and therefore, not considered.

Table 3 — Interior design temperature and corresponding relative humidity for summer

	Category 1		Category 2		Category 3	
Exterior design temperature acc. Table 1 °C	Interior design temperature °C	Interior design relative humidity %	Interior design temperature °C	Interior design relative humidity %	Interior design temperature °C	Interior design relative humidity %
28	25	69	26	65	28	73
32	26	65	27	61	29	69
33	26	65	27	61	29	69
35	26	65	27	61	29	69
40	27	61	28	58	30	65
45	27	61	28	58	30	65

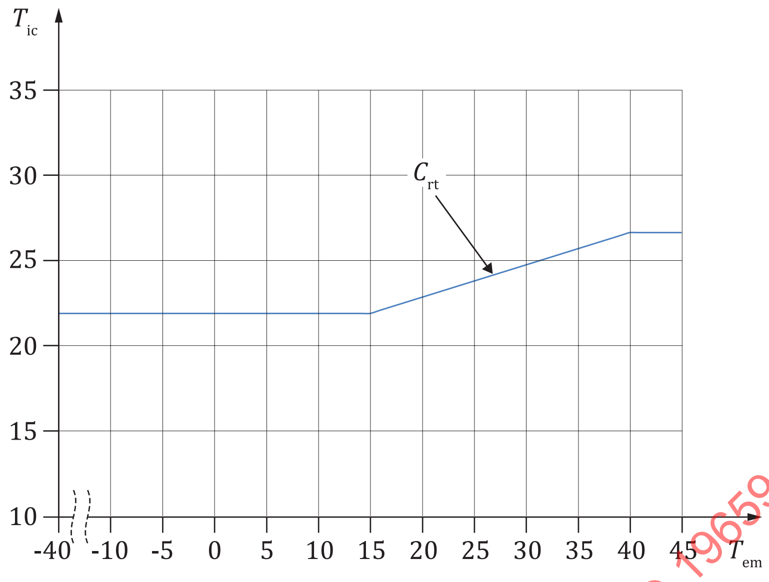
Table 4 — Interior design temperature for winter

	Category 1	Category 2	Category 3
Exterior design temperature acc. Table 2 °C	Interior design temperature °C	Interior design temperature °C	Interior design temperature °C
−40	20	18	10
−30	20	18	10
−25	20	18	10
−20	20	18	15
−10	20	18	15
0	22	20	18
5	22	20	18

6 Interior temperature setting (T_{ic})

Each vehicle shall be fitted with a regulation system which shall enable the comfort parameters specified in the technical specification to be achieved.

If not specified in the technical specification or relevant national/regional standard, the recommended temperature settings for the selected category of passenger railway vehicles shall be taken from Figure 1 to Figure 3.



Key

T_{em} mean exterior temperature, in °C

T_{ic} interior temperature setting, in °C

C_{rt} recommended interior temperature setting curve

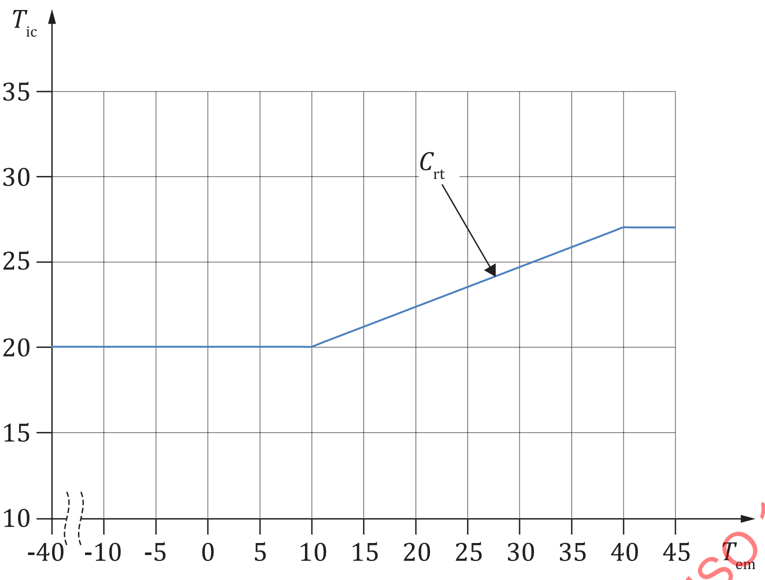
NOTE The formula of the recommended interior temperature setting curve is:

— −40 °C ≤ T_{em} < 15 °C: T_{ic} = 22 °C

— 15 °C ≤ T_{em} < 40 °C: T_{ic} = [22 + 5/25 × (T_{em} − 15)] °C

— 40 °C ≤ T_{em} < 45 °C: T_{ic} = 27 °C

Figure 1 — Interior temperature setting curve (category 1)



Key

T_{em} mean exterior temperature, °C

T_{ic} interior temperature setting, °C

C_{rt} recommended interior temperature setting curve

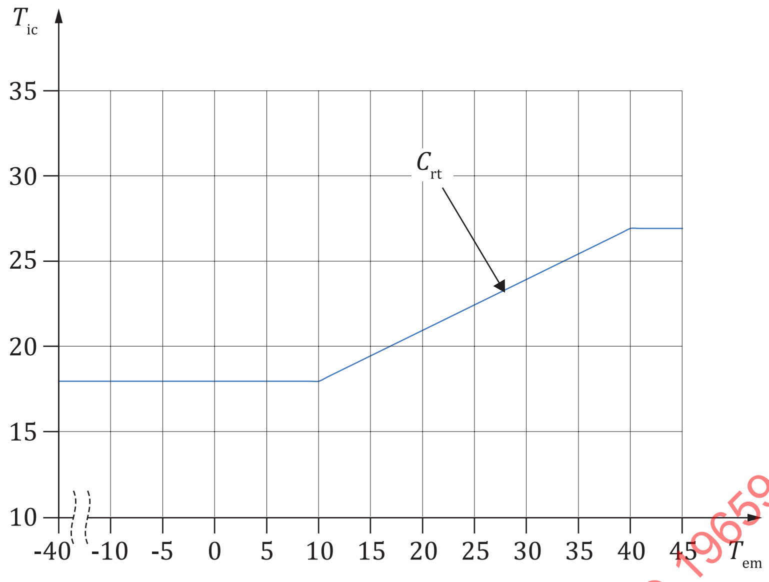
NOTE The formula of the recommended interior temperature setting curve is:

— $-40\ °C \le T_{em} < 10\ °C$: $T_{ic} = 20\ °C$

— $10\ °C \le T_{em} < 40\ °C$: $T_{ic} = [20 + 7/30 \times (T_{em} - 10)]\ °C$

— $40\ °C \le T_{em} < 45\ °C$: $T_{ic} = 27\ °C$

Figure 2 — Interior temperature setting curve (category 2)



Key

T_{em} mean exterior temperature, in °C

T_{ic} interior temperature setting, in °C

C_{rt} recommended interior temperature setting curve

NOTE The formula of the recommended interior temperature setting curve is:

— $-40\ °C \leq T_{em} < 10\ °C$: $T_{ic} = 18\ °C$

— $10\ °C \leq T_{em} < 40\ °C$: $T_{ic} = [18 + 9/30 \times (T_{em} - 10)]\ °C$

— $40\ °C \leq T_{em} < 45\ °C$: $T_{ic} = 27\ °C$

Figure 3 — Interior temperature setting curve (category 3)

These recommended interior temperature setting curves correspond to ±1 of the predicted mean vote (PMV), specified in ISO 7730, under the specific boundary conditions used in the calculation as described in Annex B.

The interior temperature setting 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 5.4.2.

Due to the limitation of the design cooling or heating capacity, the control setting temperature may not be achieved under highly demanding exterior/interior conditions, which could also apply to the design conditions. In this case, the deviation between T_{im} and T_{ic} may only be reduced under less demanding conditions.

7 Thermal comfort parameters

7.1 General

The sensation of thermal comfort varies from passenger requirements in different regions and countries.

Unless specified in the technical specification or relevant national/regional standard, the following should be considered depending on the selected category (see Clause 4):

- interior air temperature in the comfort zone, including
  - mean interior temperature range,
  - horizontal temperature range, and
  - vertical temperature range;
- relative humidity in the comfort zone;
- surface temperature on the comfort envelope;
- air velocity in the comfort zone;
- interior temperature in the local annex;
- air quality, including
  - fresh air volume flow rate into the comfort zone,
  - particulate filtration of the air, and
  - air transfer between interior zones.

7.2 Interior air temperature in the comfort zone

7.2.1 Mean interior temperature range (difference between T_{im} and T_{ic})

To ensure an adequate general thermal comfort in the comfort zones, a mean interior temperature range between T_{im} and T_{ic} should be specified. The values of Table 5 can be used.

7.2.2 Horizontal temperature range (ΔT_h)

To ensure an adequate thermal comfort for all seated and standing passengers in the comfort zones, a horizontal temperature range should be specified. The values of Table 5 can be used.

7.2.3 Vertical temperature range (ΔT_v)

To ensure an adequate thermal comfort for individual seated and standing passengers in the comfort zones, a vertical temperature range should be specified. The values of Table 5 can be used.

Table 5 — Values for temperature range

	Category 1	Category 2	Category 3
Difference T_{im} to T_{ic}	$T_{im} = T_{ic} \pm 1$ K	$T_{im} = T_{ic} \pm 1{,}5$ K	$T_{im} = T_{ic} \pm 2$ K
Horizontal T_i range	$(T_{i,max} - T_{i,min}) \leq 2$ K	$(T_{i,max} - T_{i,min}) \leq 4$ K	$(T_{i,max} - T_{i,min}) \leq 8$ K
Vertical T_i range	$(T_{i,max} - T_{i,min}) \leq 3$ K	$(T_{i,max} - T_{i,min}) \leq 6$ K	$(T_{i,max} - T_{i,min}) \leq 8$ K
NOTE T_i is the local air temperature; T_{im} is the mean interior temperature; T_{ic} is the interior temperature setting for comfort zone, in °C.			

7.3 Relative humidity in the comfort zone

To avoid excessive humidity, requirements on relative humidity for summer should be specified.

Generally, human beings are most comfortable between 40 % and 60 % relative humidity.

In railway vehicles, it is not always possible to achieve this range of relative humidity because in winter there is typically no humidification function and in summer there is typically no active humidity control.

Mainly at higher interior temperatures higher relative humidity impacts the comfort negatively. The cooling function normally implies also certain dehumidification at conditions other than the ones used for design (see Table 3).

If the relative humidity should be reduced further, the performances of this dehumidification function should be specified in terms of parameters to be achieved. This could have an impact on cooling capacity, energy consumption and outline dimension of the HVAC unit.

7.4 Surface temperature on the comfort envelope

Generally, the passenger comfort is influenced by the temperature difference between the human body and surrounding surfaces (e.g. windows, walls, floor or ceiling).

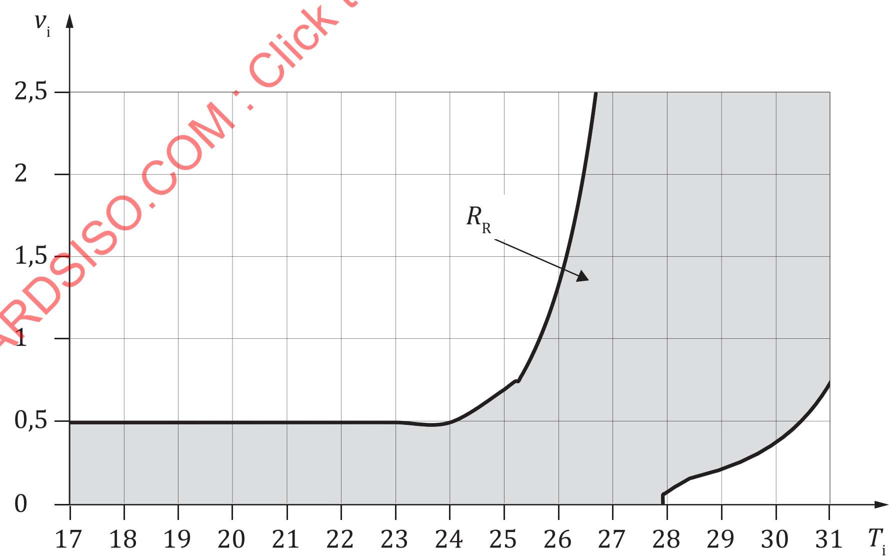
To avoid excessive temperature differences, the requirements for either surface temperatures or thermal insulation should be specified.

Maximum temperature difference between surface temperature and mean interior temperature shall be specified, when surface temperature is required.

7.5 Air velocity in the comfort zone

A high air velocity is desirable at high temperatures and humidity, while a low air velocity is desirable at low temperatures.

Figure 4 shows the recommended air velocity range for thermal comfort at local air temperature which is measured at a given measuring point. Increased air velocity is used to offset the warmth sensation caused by increased temperature.



Key

T_i local air temperature (°C)

R_R recommended range

v_i local air velocity (m/s)

Figure 4 — Air velocity range

NOTE The recommended air velocity range over 25 °C is derived based on ASHRAE 55-2010 under the specific boundary conditions used in the calculation as described in Annex C.

7.6 Interior temperature in the local annexes

Since passengers stay for short periods of time in a local annex, only temperature recommendations are specified, depending on the vehicle categories.

The values in Table 6 are recommended for interior temperature in the local annexes.

Table 6 — Interior temperature in the local annexes

Location	Vehicle type	
	Category 1	Category 2/Category 3
washroom/toilet	at a height of 1,1 m $T_{ic} - 6\ K \leq T_{im} \leq T_{ic} + 6\ K$	at a height of 1,1 m $T_{ic} - 6\ K \leq T_{im} \leq T_{ic} + 6\ K$
side corridor/telephone area/smoking area	at a height of 1,7 m $T_{ic} - 6\ K \leq T_{im} \leq T_{ic} + 6\ K$	—
vestibules	at a height of 1,7 m <heating> $10\ °C \leq T_{im} \leq 24\ °C$ <cooling> $T_{im} \leq 35\ °C$	at a height of 1,7 m <heating> $10\ °C \leq T_{im} \leq 24\ °C$ <cooling> $T_{im} \leq 35\ °C$
nursery	at a height of 1,1 m $T_{ic} \leq T_{im} \leq T_{ic} + 4\ K$	at a height of 1,1 m $T_{ic} - 6\ K \leq T_{im} \leq T_{ic} + 6\ K$
staff resting or desk-working conductor's room	at a height of 1,1 m $T_{ic} - 3\ K \leq T_{im} \leq T_{ic} + 3\ K$	at a height of 1,1 m $T_{ic} - 3\ K \leq T_{im} \leq T_{ic} + 3\ K$
other staff areas catering service area	with catering load at a height of 1,7 m $T_{im} \leq 30\ °C$	with catering load at a height of 1,7 m $T_{im} \leq 30\ °C$
NOTE T_{im} is the mean interior temperature in each local annex, in °C. T_{ic} is the interior temperature setting for comfort zone, in °C.		

7.7 Air quality

7.7.1 Fresh air volume flow rate into the comfort zone

The values of Table 7 are recommended for fresh air volume flow rate. For category 1, this should be maintained by forced air ventilation only. For category 2 and category 3, this may be maintained by forced air ventilation or a mixture of forced and natural air ventilation.

Table 7 — Minimum fresh air volume flow rate into the comfort zone

	Vehicle type		
	Category 1	Category 2	Category 3
Minimum fresh air volume flow rate m^3/h/person	10	10	8

It is possible to interrupt the fresh air volume flow for some special operational modes (e.g. pressure protection device is working). In such cases, the concentration of CO_2 shall be measured or calculated.

The temporal concentration variation inside the coach is governed by the following differential equation:

$$V\left[\frac{\partial\left(C_{\text{int,t}}\right)}{\partial t}\right]=\frac{\left[qvf\cdot C_{\text{ext}}\right]-\left[qvf\cdot C_{\text{int,t}}\right]}{3\,600}+\frac{n\cdot Q_{\text{P}}}{1\,000\cdot 3\,600}\cdot 10^{6}$$

where

$C_{int,t}$	is the CO_2 concentration in the coach at time, t, in ppm;
C_{ext}	is the CO_2 concentration in the fresh air, in ppm;
V	is the free volume inside the coach, i.e. the air volume not taken up by the passengers, in m^3;
qvf	is the fresh air volume flow rate, in m^3/h;
n	is the number of persons;
Q_p	is the quantity of CO_2 generated by one person, in l/h.

7.7.2 Particulate filtration of the air

The purpose of filtering is to remove particles such as floating dust from the fresh air and/or the return air.

The recommended filter class is coarse 60 % for category 1 and coarse 40 % for category 2 and category 3 according to ISO 16890-1.

7.7.3 Air transfer between interior zones

The HVAC system shall be designed to prevent the transfer of smoke and odours into the comfort zones during the normal operation. In particular, this should be applied for catering service areas, smoking areas, toilets and washrooms.

8 Air movement tests

8.1 General

Air movement in a passenger railway vehicle is an essential element of comfort. The tests shall be carried out under the following conditions when the:

— vehicle is at zero speed and protected from bad weather;

— wind speed is between 0 km/h and 15 km/h;

— exterior temperature is between +15 °C and +30 °C.

8.2 Air volume flow rate

The fresh air volume flow rate should be measured for typical operation modes in accordance with 11.6. If it is difficult to measure the fresh air volume flow rate, an alternative method should be mutually agreed by the contracting parties.

It is recommended to measure the air volume flow rate of the exhaust air, the return air and/or the conditioned air and/or the mixed air, and the internal pressure, as appropriate.

It is recommended to analyse the impact of the train speed on the fresh air volume flow rate by measurement or calculation.

8.3 Air velocity

The air velocity in the comfort zone shall be measured. When the distribution of air flows is different in heating, cooling or ventilation mode, air velocity shall be measured in each mode.

Unless specified in the technical specification or relevant national/regional standard, it is recommended to determine the measuring position in accordance with 12.2.5.

The status (operational or not) of the supplementary fan system during the air velocity measurement shall be indicated in the technical specification.

8.4 Air transfer between interior zones

Air transfer shall be verified so that transfer of smoke and odours into the comfort zones, in particular, from the catering service areas, the smoking areas and toilets/washrooms, is prevented during normal operation.

If verification by air volume flow rate measurement is not applicable, this can be visualized between the two relative areas by the movement of smoke generated by a smoke machine, or it can be verified by measuring the differential pressure.

9 Climatic tests

9.1 General

There are static tests and dynamic tests to evaluate function, performance, thermal comfort parameters and reliability of the HVAC system installed on a passenger railway vehicle.

Static tests are performed in a climatic chamber and dynamic tests are performed either in a climatic wind tunnel or in the field.

All or single static and dynamic tests may be performed by simulation if the contracting parties agree.

It is preferable to perform tests in a climatic facility that provides and maintains external conditions (temperature, relative humidity, wind speed and equivalent solar load) within the necessary tolerances.

The test conditions should be specified in the technical specification including the necessity of the test itself. In the absence of any detail the test programme described in 9.3 is recommended. The order of the tests is not mandatory but shall be compatible with the physical characteristic of the climatic facility and the means of measurement.

Should other equipment such as doors, equipment for toilet, power supply, lighting and special equipment need to be tested, these tests shall not interfere with the tests on the HVAC systems.

Air movement tests as specified in Clause 8 shall be carried out and verified prior to tests defined in 9.2.

The following tests are recommended in addition to tests defined in 9.2:

— air leakage test of the air distribution system;

— functional test of components in the vehicle relevant for the thermal comfort test (e.g. doors, lighting and power supply);

— water tightness test of the vehicle which influences thermal performance;

— cooling and heating performance tests of the HVAC unit;

— test of the overall heat transfer coefficient of the vehicle, if measuring for verification is necessary; and

— performance test of pre-heating, pre-cooling, the standby mode operation and the degraded mode operation of the HVAC system.

NOTE This climatic test is generally applicable to the type tests of new designed vehicles including installation of new designed components such as the HVAC unit and/or air ducts.

9.2 Type of tests

9.2.1 General

The purpose of these tests is to validate:

- the cooling and heating performance and the thermal comfort in design conditions (full load condition);
- the availability of the cooling and heating functions at the designed extreme conditions;
- the thermal comfort under the part load condition;
- the level of recovery from temporary variation of mean interior temperature caused by a door opening at station stops.

9.2.2 Design conditions test

The recommended test conditions are specified in 9.3. After the setting parameters have reached the stabilised condition (see ISO 19659-1:2017, 3.8.2), the test shall continue for 60 minutes or for three similar consecutive control cycles. The results obtained shall satisfy the requirements as specified in Clause 7.

The cooling performance tests should be carried out in a static condition.

For heating performance testing, it is recommended to simulate the maximum operational train speed.

If this is not possible, the heating performance can be demonstrated by increasing the required temperature difference between T_{im} and T_{em}.

If the heating capacity is limited, due to a combination of increased T_{im} and fixed setting of the heater safety devices, for example, the resultant reduced heating capacity can be used to extrapolate the temperature difference between T_{im} and T_{em} at full heating capacity.

This methodology does not include any air leakages or other aerodynamic effects.

For the duration of the tests, all doors shall be closed.

9.2.3 Extreme conditions test

The recommended test conditions are specified in 9.3. Testing should be performed for at least 60 minutes. It is recommended to start the testing at the design conditions and to change the exterior temperature with a maximum gradient of 3 K/h until the defined extreme conditions are reached.

For the duration of the tests, all doors shall be closed.

9.2.4 Regulation test

The recommended test conditions are specified in 9.3.

- regulation 1 is for part load cooling;
- regulation 2 is for part load cooling — only if humidity control is available;
- regulation 3 is for part load heating.

Once the parameters have reached a stabilised condition (see ISO 19659-1:2017, 3.8.2), the test shall be continued at least 60 minutes or three similar consecutive control cycles. The results obtained shall satisfy the requirements specified in Clause 7.

For the duration of the tests, all doors shall be closed.

9.2.5 Door open/close cycling test

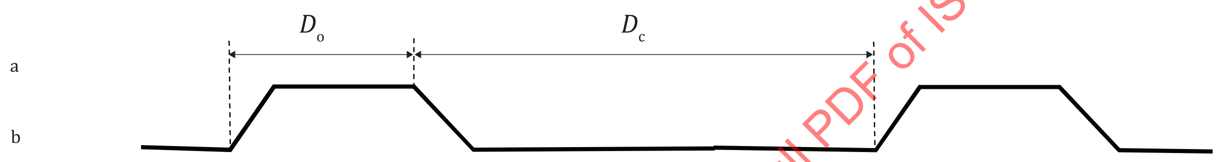
The recommended test conditions are specified in 9.3.

The door cycling time should be specified in the technical specification. However, in the absence of any detail in the specification, the following procedures are recommended:

— For category 2 vehicles: 10 operational cycles with a door open time of 30 seconds and a door close time of 5 minutes;

— For category 3 vehicles: 10 operational cycles with a door open time of 20 seconds and a door close time of 2 minutes.

The recommended definition of door open time and door close time is shown in Figure 5.



Key

D_o door open time: duration from the door opening command until the door closing command

D_c door close time: duration from the door closing command until the door opening command

a Door fully open.

b Door fully closed.

Figure 5 — Explanation of door open and close times

At the end of the door cycling test, the mean interior temperature shall be within the range specified in 7.2.1.

It is suggested that this test should be carried out only for heating after the completion of regulation test 3.

All doors on one side of the vehicle are opened and closed and all doors on the other side stay closed during the test. This test is not applicable to category 1 vehicles.

9.3 Test programme

This subclause specifies recommended test programmes, which describe the test conditions and sequences as specified in 9.2. For all categories, Table 8 and Table 9 give a recommended test programme for cooling and Table 10 and Table 11 for heating.

For all tests, the interior temperature setting, T_{ic}, shall comply with the technical specification. In the absence of any specified value, the recommended interior temperature setting, T_{ic}, in Clause 6 should apply.

Table 8 — Cooling tests for all categories

Test description	Climatic chamber			Passenger load	Solar load	Remark
	T_{em} °C	*RH* %	Wind speed km/h	%	%	
Design condition	T_{em1}	RH_{em1}	0 to 15	100	100	Full load cooling
Extreme condition	T_{em2}	RH_{em2}	0 to 15	100	100	Function test
Regulation 1	T_{em3}	RH_{em3}	0 to 15	50	50	Part load cooling
Regulation 2	T_{em4}	RH_{em4}	0 to 15	50	0	Humidity control available (optional)

NOTE The values in this table are defined as follows:

— passenger load: 100 % correspond to the value selected in 5.4.1.

— solar load: 100 % correspond to the value selected in 5.2.3.

— T_{em1}: external temperature defined for the climatic design condition (refer to 5.2.2).

— RH_{em1}: external relative humidity defined for the climatic design condition (refer to 5.2.2).

— T_{em2}: extreme external temperature defined in 5.3.

— RH_{em2}: The same absolute humidity value as climatic design condition (T_{em1}/RH_{em1}) is used for this extreme condition test.

T_{em3}, RH_{em3}, T_{em4} and RH_{em4} shall be specified in the technical specification. In the absence of any specified values, refer to Table 9.

Table 9 — Cooling tests for regulation 1 and 2

Climatic design condition	T_{em3} °C	RH_{em3} %	T_{em4} °C	RH_{em4} %
TS1	25	60	22	80
TS2	26	55	22	80
TS3	28	70	22	80
TS4	28	70	22	80
TS5	28	70	22	80
TS6	28	70	22	80
TS7	28	70	22	80
TS8	28	70	22	80
TS9	28	70	22	80
TS10	28	45	—	—
TS11	35	60	28	60

Table 10 — Heating tests for all categories

Test description	Climatic chamber[a]			Passenger load	Solar load	Remark
	T_{em} °C	RH %	Wind speed km/h	%	%	
Design condition	T_{em5}	—	Maximum speed	0	0	Full load heating
Extreme condition	T_{em6}	—	0 to 15	0	0	Function test
Regulation 3	T_{em7}	—	0 to 15	0	0	Part load heating
Door open/close	T_{em7}	—	0 to 15	0	0	Door open/close cycling test

[a] Regarding the "maximum speed", refer to 9.2.2.

NOTE The values in this table are defined as follows:

— T_{em5}: external temperature defined for the climatic design condition (refer to 5.2.2);

— T_{em6}: extreme external temperature defined in 5.3.

T_{em7} shall be specified in the technical specification. In the absence of any specified value, refer to Table 11.

Door open/close cycling test is not applicable to category 1 vehicles.

Table 11 — Heating tests for regulation 3

Climatic design condition	T_{em7} °C
TW1	0
TW2	0
TW3	0
TW4	0
TW5	0
TW6	5
TW7	—

10 Characteristics of the test facility and equipment

10.1 General

The test facility and equipment should be capable of providing and maintaining the temperature, relative humidity, occupation, wind speed (if required) and equivalent solar load within the necessary tolerances. These tolerances should be specified in the technical specification. In the absence of any detail in the specification, the following subclauses, 10.2 to 10.6 are recommended to apply.

10.2 Exterior temperature

Variation of the mean exterior temperature during the test is preferable within ±1 K. The exterior temperature distribution is preferable within ±3 K.

10.3 Relative humidity

Variation of the relative humidity during cooling tests is preferable within ±5 %.

10.4 Occupation

Appropriately sized heating and humidity generating equipment should be provided and evenly distributed inside the car to simulate the latent and sensible heat loads. The tolerance for each heat load during the test is preferable within ±5 %.

There shall be no direct influence of the latent and sensible heat loads on the measuring sensors.

10.5 Wind speed (if required)

For wind speed simulation, suitable aerodynamic conditions around the train should be realised. The wind speed stability during the test is preferable within ±1 m/s.

10.6 Equivalent solar load

Equivalent solar load is simulated by the lamps outside the vehicle or by the electric heaters inside the vehicle which give an equivalent solar load. Variation of overall equivalent solar load during the test is preferable within ±5 %.

In case lamps are used for simulating the solar load, the characteristics of the lamps shall follow Table 12, which is in accordance with the definition of CIE 85 for the terrestrial radiation.

Table 12 — Solar lamp characteristics

Wavelength nm	Total radiation compared with terrestrial radiation, given in CIE 85 %	Allowable variation %
280 to 400	6,1	±3
400 to 800	51,8	±5
800 to 3 000	42,1	±5

11 Recording and measuring instruments

11.1 General

Recording and measuring instruments should be specified in the technical specification. All measuring instruments shall be calibrated at a regular interval. In the absence of any detail in the specification, the following subclauses, 11.2 to 11.9 are recommended to apply.

11.2 Recording

A computer-based data acquisition system with sufficient input channels to record the required data is recommended and the recording should be continuous, with a minimum base sampling rate of one measurement per minute for all values recorded.

Data files should be easily exportable to common spreadsheet programmes.

11.3 Temperature

The temperature range of the measuring instruments should comply with ISO 7726:1998, Table 2. Care should be taken to prevent the probe from being subjected to solar radiation or neighbouring heat sources.

11.4 Relative humidity

The measuring instruments used should be comparable to the requirements for partial water vapour pressure Class C of ISO 7726:1998, Table 2.

11.5 Air velocity

The measuring instruments used should be Class C of ISO 7726:1998, Table 2.

11.6 Air volume flow rate

The measurement of the air volume flow rate should be achieved by a calibrated system of measurement within a minimum accuracy of 10 %.

NOTE It is not necessary to carry out a continuous recording of these measurements.

At the same time, the exterior temperature and the barometric pressure should be recorded. The air volume flow rate shall be measured with fan operation only.

11.7 Wind speed (if required)

The measurement of the wind speed around the vehicle should be achieved by a calibrated system of measurement within a minimum accuracy of ±1 m/s.

11.8 Equivalent solar load (if required)

The measurement of the equivalent solar energy should be achieved by a calibrated system of measurement. If lamps are used for simulating the solar load, the calibration should be done with a pyranometer, First Class, according to ISO 9060.

11.9 Energy consumption and power rating

The measurements should be carried out within an accuracy of 2,5 %.

12 Position of measuring points

12.1 General

For verification of the performance of the HVAC system for thermal comfort, the measuring positions and points should be specified in the technical specification.

In the absence of any requirements in the technical specification, subclauses 12.2 to 12.4 should be applied.

12.2 Position of sensors in the passenger railway vehicle

12.2.1 General

The measuring position should be taken from above floor level at:

— 0,1 m (foot height);

— 1,1 m (sitting passenger at head height); and

— 1,7 m (standing passenger at head height).

12.2.2 Interior air temperature

To obtain the mean interior temperature, the measurement should be taken by evenly distributed temperature sensors at the height of 1,1 m above floor level. The recommended minimum number of sensors at this height is eight per vehicle.

To obtain the horizontal temperature range, the same sensors shall be used.

To obtain the vertical temperature range, the range shall be measured at three evenly distributed positions. At each position, the interior air temperature shall be measured at 0,1 m, 1,1 m and 1,7 m above floor level.

12.2.3 Relative humidity

Relative humidity shall be measured at least one point, situated in the middle of the vehicle at 1,1 m above floor level.

12.2.4 Surface temperature

There shall be at least two sensors per side wall, floor and ceiling at representative positions.

12.2.5 Air velocity

The local air velocity shall be measured at 1,1 m above floor level for category 1 and at 1,1 m and 1,7 m above floor level for category 2 and category 3, as used for the vertical temperature range.

12.2.6 Interior temperature in the local annex

The measuring position of the temperature in the local annex is placed geometrically at the centre of the annex. Heights are given in Table 6.

12.3 Position of sensors in the test facility

12.3.1 General

The measuring positions should be at representative positions in the test facility.

12.3.2 Exterior air temperature

To obtain the mean exterior temperature, a minimum of two air temperature sensors per vehicle shall be taken into account.

In addition, at least one air temperature sensor shall be placed at one representative fresh air inlet of the vehicle.

12.3.3 Relative humidity

In combination with every air temperature sensor located at a fresh air inlet, the relative humidity shall be measured at the same position.

12.3.4 Wind speed (if required)

The wind speed shall be measured at the geometric centre of the vehicle side wall at the distance of at least 0,1 m from the side wall.

12.3.5 Equivalent solar load (if required)

The sensor for the equivalent solar load measurement should be placed directly on the sunny side wall of the vehicle.

12.4 Position of sensors for testing where no test facility exists

12.4.1 General

The measuring positions should be at representative positions close to the vehicle.

12.4.2 Exterior air temperature

To obtain the mean exterior temperature, a minimum of two air temperature sensors per vehicle shall be taken into account.

In addition, at least one air temperature sensor shall be placed at a representative place of the vehicle.

12.4.3 Relative humidity

In combination with every air temperature sensor located at a representative place, the relative humidity shall be measured at the same position.

12.4.4 Wind speed

The wind speed shall be measured at the geometric centre of the vehicle side wall at the distance of at least 0,1 m from the side wall. However, the vehicle speed may be used to substitute the measurement of wind speed.

12.4.5 Solar load (if required)

The sensors for the solar load measurement shall be placed directly on the sunny side wall and roof of the vehicle.

Annex A
(informative)

Example of exterior design temperature and corresponding relative humidity

A.1 General

Exterior design parameters required in the relevant Japanese standard (JIS), Chinese standard (GB) and European standard (EN), and exterior design parameters recommended in the relevant ASHRAE Guideline are provided as a reference.

A.2 Japanese standard: JIS E 6603

Cooling: 33 °C/69 %RH

Heating: 0 °C/65 %RH

A.3 Chinese standards: GB/T 33193.1

Cooling: Zone I: 40 °C/46 %RH

Zone II: 35 °C/60 %RH

Zone III: 28 °C/50 %RH

Heating: Zone I: −10 °C

Zone II: −25 °C

Zone III: −40 °C

A.4 European standards: EN 13129, EN 14750

Cooling: Zone I: 40 °C/40 %RH

Zone II: 35 °C/50 %RH

Zone III: 28 °C/45 %RH

Heating: Zone I: −10 °C

Zone II: −20 °C

Zone III: −40 °C

A.5 ASHRAE Guideline 23-2016

A.5.1 Cooling

ASHRAE 0,4 %, 1,0 %, and 2,0 % cooling dry-bulb temperature/mean coincident wet-bulb temperature data are typically used to determine the required cooling capacity of rail HVAC equipment. Unless otherwise indicated in the project technical specification, the value of 0,4 % data is recommended.

A.5.2 Heating

Unless otherwise indicated in the project technical specification, ASHRAE 99,6 % heating dry-bulb temperature data is recommended for determining the required heating capacity of the HVAC equipment.