INTERNATIONAL STANDARD

# ISO 19659-3

First edition
2022-10

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

## Part 3: Energy efficiency

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

*Partie 3: Efficacité énergétique*



Reference number
ISO 19659-3:2022(E)

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# Foreword

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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

The world's energy resources are being consumed at a significant rate that will result in the depletion of non-renewable resources. It is imperative that energy be conserved. Conservation of energy in railway vehicles can result in a slowdown of non-renewable resource usage and consequently of the build-up of greenhouse gases.

The HVAC (heating, ventilation and air-conditioning) system is one of the main energy consumers on a train, and its energy efficiency is a key issue to reduce the environmental impact of public transport.

As most railway vehicles are designed to last for a long period (15 y to 40 y), lower energy consumption can also be considered a means of reducing the cost to railway operators and authorities.

The energy consumption of the HVAC systems is affected by multiple parameters therefore, a common guideline is essential for comparative assessment of energy efficiency between different systems.

This document offers methodologies to deliver comparable energy consumption values of the HVAC system without unnecessary lead times and costs by suggesting appropriate conditions for simulation or testing.

In general, this document describes the conditions that should be considered:

- train mode,
- principles such as measurements, climatic and operational boundary conditions,
- assessment methods such as simulation, calculation, verification and post-processing.



These can be used to assess the effectiveness of energy efficiency measures to evaluate different cars and/or HVAC concepts and to provide an indication of the annual HVAC energy consumption for the whole train (except driver's cab).



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

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

# Part 3: Energy efficiency

## 1 Scope

This document is applicable to the calculation, measurement and/or verification of energy consumption of railway vehicle HVAC (heating, ventilation and air-conditioning) systems.

The HVAC system energy consumption is simulated, calculated, measured and validated in accordance with the requirements of thermal comfort defined in ISO 19659-2, considering the same category of passenger railway vehicles as detailed in ISO 19659-2, Clause 4:

— Category 1 (e.g. main line, intercity, long distance, high speed);

— Category 2 (e.g. suburban, commuter, regional);

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



This document only covers the passenger area HVAC systems. Driver's cab HVAC systems are excluded but could be treated in a similar way.

## 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*

ISO 19659-2, *Railway applications — Heating, ventilation and air conditioning systems for rolling stock — Part 2: Thermal comfort*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

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

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

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

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

### 3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

 

TISM Train in-service mode

TRSM Train ready for service mode

PCM Pre-conditioning mode

PM Parking mode

# 4 Train mode

## 4.1 General

The following train modes, 4.2 to 4.5 are the different operating states of train and relate to the operating mode of the HVAC system.

## 4.2 Train in-service mode (TISM)

This mode covers the commercial operation of the train, including several passenger load cases. The train is moving or is stationary with the HVAC system running in its automatic mode.

## 4.3 Train ready for service mode (TRSM)

In this mode, the HVAC system is operational (same as for TISM) without passengers.



This situation occurs frequently, for example when the:

— train is waiting between two commercial runs;

— train is at a terminal station with the doors closed;

— train is in operation between a depot and a terminal station.

When the train is being cleaned at a terminal station, the time should be considered for this mode.

## 4.4 Pre-conditioning mode (PCM)

Pre-conditioning is the process which enables the interior temperature to be lowered or raised to a defined comfort level including pre-cooling and pre-heating. This mode will depend on the ambient temperature conditions at which the train is operating. During hot conditions pre-cooling is required and in cold conditions, pre-heating is required.

This mode of operation is without passengers on the train.

This mode is an option. If the customer requires this mode, the detailed requirements shall be specified in the technical specification.

## 4.5 Parking mode (PM)

Parking mode is used when the train is not in operation, and there are no staff or passengers on board. The HVAC system runs normally with different setpoints for temperature and airflow or alternatively, is shut down to conserve energy.

The purpose of parking mode includes frost protection and keeping the interior temperature at a reasonable level. Trains are normally shut down during the night to reduce noise and energy consumption.

This mode is an option. If the customer requires this mode, the detailed requirements shall be specified in the technical specification.

### 4.6 Operating timetable, hours for each mode and category

Operating timetables and the number of hours for each train mode and category shall be specified in the technical specification. If values are not available in the technical specification, the values can be selected from Table 1.

**Table 1 — Train mode (timetable and operating hours)**

| Train mode | Category 1 | | Category 2 and Category 3 | |
|---|---|---|---|---|
| | Timetable | Operating hours | Timetable | Operating hours |
| TISM | 5:00 to 24:00 | 12 h/day | 5:00 to 24:00 | 14 h/day |
| TRSM | 5:00 to 24:00<br>excluding peak<br>time<br>7:00 to 9:00<br>17:00 to 19:00 | 4 h/day | 5:00 to 24:00<br>excluding peak<br>time<br>7:00 to 9:00<br>17:00 to 19:00 | 2 h/day |
| [**Option**]<br>PCM | 5:00 to 24:00<br>excluding peak<br>time<br>7:00 to 9:00<br>17:00 to 19:00 | 0,5 h/day | 5:00 to 24:00<br>excluding peak<br>time shown above<br>7:00 to 9:00<br>17:00 to 19:00 | 0,5 h/day |
| [**Option**]<br>PM | 1) 0:00 to 5:00<br>2) 5:00 to 24:00<br>rest of the time<br>excluding the<br>three modes<br>shown above | 1) 5 h/day<br>2) 2,5 h/day<br>addition of all<br>parking mode<br>periods 7,5 h/day<br>includes switch on<br>and switch off | 1) 0:00 to 5:00<br>2) 5:00 to 24:00<br>rest of the time<br>excluding the<br>three modes<br>shown above | 1) 5 h/day<br>2) 2,5 h/day<br>addition of all<br>parking mode<br>periods 7,5 h/day<br>includes switch on<br>and switch off |
| Total | | 24 h | | 24 h |



## 5 Principles

### 5.1 General

The energy consumption of a HVAC system could be measured on an in-service train for a certain period. Cycles for the HVAC system energy consumption would have to include annual cycles, or at least daily cycles for several days during a year, covering seasonal influences. This method is very time consuming and expensive with poor repeatability regarding the results. Furthermore, simulation of energy consumption for transient conditions in the HVAC system is difficult and not state of the art in view of a precise prediction of energy consumption.

Therefore, a different method shall be applied for the energy consumption of the HVAC system.

A matrix of steady-state operational points is defined to represent the annual climatic and operational conditions. It might be necessary to define different operational points depending on the respective region where the train is operating.

Each operational point is defined by the exterior temperature, corresponding relative humidity, passenger load and equivalent solar load. All operational points are defined at zero train speed.

Weather data to represent the local weather is collected and classified to prepare the data subset for each train mode and category.

Annual operating hours and weighting factors for each operational point are calculated based on the collected weather data to estimate the total annual energy consumption of the HVAC system.

The energy consumption of the operational points shall be calculated and later be verified by either:

— measurements in a climatic facility (Method I); or

— measurements on a train placed on a track in an outdoor environment, for example in a depot or siding at zero train speed of the vehicle (Method II).

One of these two methods shall be chosen prior to the calculation and validation.

## 5.2 Methods

### 5.2.1 General

Operational points shall be chosen in accordance with local climatic conditions and shall be selected following procedure described in 5.3.2.

The passenger load shall be applied using people or simulated by heat and humidity sources as described in ISO 19659-2, 10.4.



### 5.2.2 Method I [with climatic facility / ISO 19659-2]

The energy consumption is measured in a climatic facility in accordance with ISO 19659-2, Clause 10.

### 5.2.3 Method II [without climatic facility]

The energy consumption is measured on a train placed on a track in an outdoor environment, for example in a depot or siding at zero train speed. Since the environmental conditions cannot be influenced in a similar way as in a climatic facility, the environmental conditions are to remain within the tolerance as defined in 6.3.2.

## 5.3 Climatic and operational boundary conditions

### 5.3.1 General

Climatic and operational boundary conditions shall be representative of the local area to estimate energy consumption appropriately.

In this subclause the procedure for decision of operational point matrix, collection and analysis of weather data, calculation of annual operating hours and weighting factor are introduced with some examples.

The information is applicable for simulation, calculation and verification of energy consumption in 6.2 and 6.3.

### 5.3.2 Operational point matrix

A matrix of steady-state operational points for each train mode is defined to represent the annual climatic and operational conditions for the local area.

Table 2 gives typical operational points for cold, mild and hot areas in case of TISM and TRSM. This table contains values for $T_{em1}$, $T_{em3}$, $T_{em4}$, $T_{em5}$, $T_{em7}$ in Table 1, Table 2, Table 9, Table 11 of ISO 19659-2. In order to cover the complete temperature range for calculation of annual energy consumption, exterior temperatures 10 °C and 15 °C are added. The train is considered to be at zero train speed for all points.

 

Operational points can be selected from Table 2.

In order to ensure an optimal balance between calculation/test effort and the demand for accuracy, 6 to 8 operational points is reasonable for the calculation of annual energy consumption for TISM and TRSM.

Exterior temperature, 10 °C, 15 °C, 22 °C and 28 °C are reasonable conditions as specified operational points.

The values of corresponding relative humidity could be changed based on the local weather data analysis as necessary.

If the range of the exterior temperature between adjacent operational points is equal to or larger than 20 K, the intermediate temperature should be added (see A.2.2.3 and A.2.2.4 as examples).

For special areas such as tropical or extreme cold conditions, the number of operational points are dependent on the project.

Procedure for decision of operational point matrix is described in Annex A with some examples.

Operational point matrix for PCM and PM shall be specified in the technical specification if required.

**Table 2 — Clustering operational point matrix for TISM and TRSM**

| Specified operational points $T_{xx}$ for energy consumption analysis | | | $T_{em}$ °C | $RH_{em}$ % | Equivalent solar load % | Passenger load % | | Refer to ISO 19659-2 |
|---|---|---|---|---|---|---|---|---|
| Cold area | Mild area | Hot area | | | | TISM | TRSM | |
| | | | -40 | -- | 0 | 0 | 0 | $T_{em5}$ |
| | | | -30 | -- | 0 | 0 | 0 | $T_{em5}$ |
| | | | -25 | -- | 0 | 0 | 0 | $T_{em5}$ |
| | | | -20 | -- | 0 | 0 | 0 | $T_{em5}$ |
| | | | -10 | 80 | 0 | 0 | 0 | $T_{em5}$ |
| | | | 0 | 80 | 0 | 0 | 0 | $T_{em5}$, $T_{em7}$ |
| | | | 5 | 80 | 0 | 0 | 0 | $T_{em5}$, $T_{em7}$ |
| $T_{10}$ | $T_{10}$ | $T_{10}$ | 10 | 80 | 0 | 0 | 0 | - |
| $T_{15}$ | $T_{15}$ | $T_{15}$ | 15 | 80 | 0 | 50 | 0 | - |
| $T_{22}$ | $T_{22}$ | $T_{22}$ | 22 | 60 | 0 | 50 | 0 | - |
| | | | 22 | 80 | 0 | 50 | 0 | $T_{em4}$ |
| | | | 25 | 60 | 50 | 50 | 0 | $T_{em3}$ |
| | | | 26 | 55 | 50 | 50 | 0 | $T_{em3}$ |
| $T_{28}$ | $T_{28}$ | $T_{28}$ | 28 | 45 | 50 | 50 | 0 | $T_{em3}$ |
| | | | 28 | 45 (50) | 100 | 100 | 0 | $T_{em1}$ |
| | | | 28 | 60 | 0 | 50 | 0 | $T_{em4}$ |
| | | | 28 | 70 | 50 | 50 | 0 | $T_{em3}$ |
| | | | 32 | 50 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 33 | 69 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 35 | 50 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 35 | 60 | 50 | 50 | 0 | $T_{em3}$ |

NOTE

— The train is considered to be at zero train speed for all points.

— $RH_{em}$(%) for $T_{em}$ equal to or less than 10 °C is only necessary for HVAC systems equipped with a heat pump.

**Table 2** *(continued)*

| Specified operational points $T_{xx}$ for energy consumption analysis | | | $T_{em}$ °C | $RH_{em}$ % | Equivalent solar load % | Passenger load % | | Refer to ISO 19659-2 |
|---|---|---|---|---|---|---|---|---|
| Cold area | Mild area | Hot area | | | | TISM | TRSM | |
| | | | 35 | 60 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 35 | 65 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 35 | 75 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 40 | 40 (46) | 100 | 100 | 0 | $T_{em1}$ |
| | | | 40 | 60 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 45 | 10 | 100 | 100 | 0 | $T_{em1}$ |
| | | | 45 | 30 | 100 | 100 | 0 | $T_{em1}$ |

NOTE

— The train is considered to be at zero train speed for all points.

— $RH_{em}$(%) for $T_{em}$ equal to or less than 10 °C is only necessary for HVAC systems equipped with a heat pump.

### 5.3.3 Weather data analysis

#### 5.3.3.1 General



The weather data which represents the local weather is collected and classified based on operating timetable and operating hours corresponding to each train mode and category. Then, the annual operating hours and the weighting factor for each operational point are calculated to estimate the total annual energy consumption of the HVAC system.



#### 5.3.3.2 Collection of Weather data

The weather data considered for the energy consumption shall be representative of the local weather.

The minimum requirements for the contents of the weather data:

— weather data shall be from a validated source;

— recent weather data source is recommended. (ideally not older than ten years);

— the data shall cover a period of at least five complete years to average;

— it is recommended to consider at least one data per hour;

— the minimum data shall be the exterior temperature (protected from the sun and wind).

Collected weather data is classified based on operating timetable and operating hours corresponding to each train mode and category as defined in Table 1, for the preparation of annual operating hours and weighting factor calculation.

The procedure for the collection of weather data, as an example, is described in Annex B. One location is selected to introduce the procedure for weather data analysis. For the usage of the train in a large region common for Category 1, the weather data of several representative locations could be used and averaged. In that case, the annual operating hours in 5.3.3.4 can be obtained by averaging those at each location. The average weighting factor in 5.3.3.5 can be calculated from the average annual operating hours.

Operating timetable and operating hours for PCM and PM shall be specified in the technical specification if annual energy consumption for each train mode is required.

 