TECHNICAL REPORT

ISO/TR 17772-2

First edition
2018-04

Energy performance of buildings — Overall energy performance assessment procedures —

Part 2: Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings

Performance énergétique des bâtiments — Modes opératoires d'évaluation de la performance énergétique globale —

Partie 2: Lignes directrices pour l'utilisation des paramètres d'entrée de l'environnement intérieur pour la conception et l'évaluation de la performance énergétique des bâtiments

Reference number
ISO/TR 17772-2:2018(E)

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*.

Introduction

This document provides guidance to users in the application of ISO 17772-1 and gives additional background information. This document also describes and recommends additional topics related to the evaluation of the indoor environmental quality and new possibilities to improve the indoor environmental quality and reduce energy use of buildings like personalized systems, air cleaning technologies, consideration of adapted persons, etc.

This document explains how design criteria can be established and used for dimensioning of systems. It explains how to establish and define the main parameters to be used as input for building energy calculation and long-term evaluation of the indoor environment. This document also describes how gas phase air cleaning in the future can improve the indoor air quality and partly substitute for outside air. Finally, it identifies parameters to be used for monitoring and displaying of the indoor environment. Different categories of criteria can be used depending on type of building, type of occupants, type of climate and national differences. This document explains how these different categories of indoor environment can be individually selected as national criteria, be used in project agreement for design criteria and for displaying the yearly building performance in relation to indoor environmental quality. The designer can also define other categories using the principles from ISO 17772-1 and this document.

Energy performance of buildings — Overall energy performance assessment procedures —

Part 2: Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings

1 Scope

This document deals with the indoor environmental parameters for thermal environment, indoor air quality, lighting and acoustic. It explains how to use ISO 17772-1 for specifying indoor environmental input parameters for building system design and energy performance calculations.

This document:

— specifies methods for long-term evaluation of the indoor environment obtained as a result of calculations or measurements;

— specifies criteria for measurements which can be used if required to measure compliance by inspection;

— identifies parameters to be used by monitoring and displaying the indoor environment in existing buildings.

This document is applicable where the criteria for indoor environment are set by human occupancy and where the production or process does not have a major impact on indoor environment. It explains how different categories of criteria for the indoor environment can be used.

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 13731, *Ergonomics of the thermal environment — Vocabulary and symbols*

ISO 17772-1, *Energy performance of buildings — Indoor environmental quality — Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13731 and ISO 17772-1 apply.

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

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

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

4 Symbols and abbreviated terms

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52000-1:2017, Annex C, and the following apply.

Symbol	Quantity	Unit
θ_o	indoor operative temperature	°C
θ_e	outdoor temperature	°C
Θ_m	running mean outdoor air temperature	°C
$\Theta_{ed\text{-}i}$	daily mean outdoor temperature	°C
Θ_o	operative temperature, design and energy calculations	°C
$\Theta_{rm\text{-}i}$	running mean outdoor temperature	°C
v_a	air speed (average/maximum)	m/s
Θ_f	floor surface temperature	°C
ΔCO_2	concentration	ppm
$\Delta\Theta_{pr}$	radiant temperature asymmetry	K
$\Delta\Theta_a$	vertical air temperature difference	K
α	constant for running mean calculations	
q_{tot}	total ventilation rate	l/s
q_B	ventilation rate for building materials	l/s (m^2)
q_p	ventilation rate for persons	l/s (per person)
q_{tot}	total ventilation rate in occupied zone	l/s (m^2), l/s (person)
n	number of persons	
q_h	ventilation rate required for dilution of pollutant	L/s
G_h	generation of a pollutant	µg/s
$C_{h,}$	guideline value of a pollutant	µg/L
$C_{h,i}$	guideline value of the substance	µg /m^3
$C_{h,o}$	supply concentration of a pollutant at air intake	µg/L
ε_v	ventilation effectiveness	—
A	floor area	m^2
$L_{p,A}$	A-weighed sound pressure level	dB(A)
$L_{eq,\,nT,A}$	equivalent continuous sound pressure level	dB(A)
D	daylight factor	
$DC_{a,j}$	daylight quotient of the Calculated area	j
E_m	average maintained illuminance	lx
M	activity level	met
I_{cl}	assumed clothing level winter/summer	clo

4.2 Abbreviated terms

ACH	air changers per hour
DR	draught rate, %
DSNA	daylight quotient sunscreen not activated
IEQ	indoor environmental quality
IEQ_{cat}	indoor environmental quality category for design

$LPB_{1–3}$	low polluting building class
PD	percentage dissatisfied for local thermal discomfort
PMV	predicted mean vote
PPD	predicted percentage of dissatisfied, %
RH	relative humidity

5 Interactions with other standards and use of categories

This document interacts mainly with ISO 17772-1. This document explains how the indoor environmental criteria in ISO 17772-1 can be used for the design of building and HVAC systems. The thermal criteria (design indoor temperature in winter, design indoor temperature in summer) are used as input for heating and cooling load calculations and sizing of the installed systems. Ventilation rates are used for sizing ventilation systems, and lighting levels for design of lighting system including the use of day lighting. The design values for sizing the building services are needed to avoid possible negative effect of indoor environment and to give advice in respect of improvement of the energy efficiency of existing buildings as well as of the heating and cooling of buildings.

This document explains how values for the indoor environment (temperature, ventilation, lighting) are used as input to the calculation of the energy demand (building energy demand). Output from measured indoor environmental parameters in existing buildings (temperature, CO_2, ventilation rates, illumination levels) will enable the evaluation of overall annual performance and can be used to display the indoor environmental factors together with data for the energy performance.

Output from room temperature calculations and yearly dynamic building simulations will enable evaluation of the annual performance of buildings at the design stage.

This document describes methods for measurement of the indoor environment and for treating measured data related to the inspection of HVAC systems.

This document provides a method for categorization of indoor environment (Clause 10). This method can be used to integrate complex indoor environment information to simple classification for a possible indoor environment certificate.

6 How to establish design input criteria for dimensioning of buildings, heating, cooling, ventilation and lighting systems

6.1 General

Recommended input values are given for each of the different categories as shown in Table 1. These categories can be used in different ways. First and foremost, they can be used to establish different levels of criteria for the design of buildings and building services. Different countries can standardize one category for design. The consultant and client of a building project can use the categories to agree on a specific design level. The intention is not that a building should be operated strictly in one class the whole year round. Instead the categories can be used to describe the yearly indoor environmental performance of a building by showing the distribution of the parameters in the different categories. It can then, on the national level or in a design/operation contract, be specified how much of the time the categories can be exceeded. This is shown in this document with some examples.

Table 1 — Categories of indoor environmental quality

Category	Level of expectation	Explanation
IEQ_{I}	High	Should be selected for occupants with special needs (children, elderly, handicapped).
IEQ_{II}	Medium	The normal level used for design and operation.
IEQ_{III}	Moderate	Will still provide an acceptable environment. Some risk of reduced performance of the occupants.
IEQ_{IV}	Low	Should only be used for a short time of the year or in spaces with very short time of occupancy.

Even if a building is designed for category III, it can still be operated at a greater part of the year in category I or II. When the outdoor conditions are less severe (warmer in winter, colder in summer) than the design day, the capacity of the heating/cooling system will be large enough to keep the indoor environment within a narrower range.

It can be argued that selecting a higher category can increase the energy consumption. The energy requirement is, however, regulated by national building codes and cannot be exceeded. The challenge is then for the designer/operator of the building to obtain a high level of indoor environmental quality within the required energy criteria.

For design of buildings and dimensioning of room conditioning systems, the thermal comfort criteria (minimum room operative temperature in winter, maximum room operative temperature in summer) will be used as input for heating load and cooling load calculations. The design ventilation rates that are used for sizing the equipment are also used for energy calculations. The criteria are used as input values for the sizing and dimensioning of the systems as well as for design of buildings (facades, orientation, solar shading, etc.). Using a higher category will result in systems with a higher capacity; but depending on how the system is operated, the energy use is not necessarily higher. In the design a design external temperature for heating and a design day (including solar load) for cooling will normally be used.

To protect the designer/installer against complaint for not meeting the design intend, it is very important that the basis for design (boundary conditions, occupant density, etc.) are documented in the design documents. This will avoid discussions when these boundary conditions are changed during the lifetime of the building and the performance criteria cannot be met.

6.2 Thermal environment

6.2.1 General

Field studies in office buildings have shown that people's expectations regarding the thermal environment can be different for buildings with installed mechanical cooling and buildings where the occupant only have the possibility to open windows to influence the thermal environment. Therefore, the design criteria are different for the two types of office buildings: mechanical heated and cooled buildings and buildings without mechanical cooling (see the definition in ISO 17772-1). The decision on which approach to use is taken by the client together with his consultant. It is possible for the consultant to show the difference between the two methods (acceptable indoor temperatures, energy use, etc.).

6.2.2 Mechanically heated and/or cooled buildings

Criteria for the thermal environment in heated and/or cooled buildings, in ISO 17772-1 are based on the thermal comfort indices Predicted Mean Vote-Predicted Percentage of Dissatisfied (PMV-PPD) with assumed typical levels of activity and typical values of thermal insulation for clothing (winter and summer) as described in detail in ISO 7730. Assuming different criteria for the PPD, different categories of the indoor environment are established. The PMV-PPD index considers the influence of all six thermal parameters (clothing, activity, air temperature, mean radiant temperature, air velocity and humidity) and can be directly used as a criteria.

With a specified combination of activity and clothing, an assumed 50 % relative humidity and low air velocities (<0,1 m/s), the criteria can also be expressed as operative temperature as shown in Annex B. For other air velocities and humilities, the corresponding operative temperature will be different. Some examples of recommended design indoor operative temperatures for heating and cooling, derived according to this principle, are presented in Table B.2. This presents design values for the indoor operative temperature in buildings that have active heating systems in operation during winter season and active cooling systems during summer season, assumed clothing level for winter (1,0 clo) and summer (0,5 clo) and activity level (sedentary, 1,2 met). Note that the operative temperature limits should be adjusted when clothing levels and/or activity levels are different from the values mentioned in the table.

In some types of room, there can be a mixed type of occupants (sedentary-standing/walking) with different type of clothing (visitor to department store in outdoor clothing and shop assistance in indoor clothing). In these cases, a compromise should be found for the design criteria and the boundary conditions; this should be documented in the design documents and agreed by the client.

The temperatures in ISO 17772-1:2017, Table H.2) are operative temperatures (ISO 7726) with design loads at the design weather conditions which are specified nationally according to ISO 15927-4 and ISO 15927-5.

In most cases, the average room air temperature can be used as defining the design indoor temperature, but if temperatures of large room surfaces differ significantly from the air temperature (windows in winter and summer) or in situations where building occupants are often exposed to direct sun, the operative temperature should be used. Further information on clothing and activity can be found in ISO 9920 and ISO 8996. The value of design temperature can vary from the values shown, to take account of, for example, local custom (clothing) or a desire for energy saving so long as the within-day variation from the design temperature is within the given range, and the occupants are given time and opportunity to adapt to the modified design temperature.

The design criteria in this subclause are both for design of buildings (dimensioning of windows, solar shading, building mass, etc.) and for design HVAC systems.

6.2.2.1 Local thermal discomfort

Criteria for local thermal discomfort (see ISO 17772-1), such as draught, radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures, will also have an influence on the design of buildings and systems, and should be taken account of.

6.2.2.2 Personalized systems

Individual preferences regarding the indoor environment can be very different. Therefore, there is an increasing interest in using personalized systems for providing thermal comfort at individual workplaces. With personalized systems, it can be possible to satisfy all occupants. Recommended criteria for these types of systems are included in Annex L.

6.2.3 Buildings without mechanical cooling

During the summer season and during the between-seasons (spring and autumn), the so-called adaptive criteria (upper and lower temperature limits that change with the running mean outside temperature) can be applied (see the category I, II and III upper and lower limits in ISO 17772-1:2017, Figure H.2). During the winter season, the same temperature limits should be applied as presented for buildings with mechanical cooling systems.

The adaptive criteria are based on data for office buildings, but could possibly be used for other buildings of similar type used mainly for human occupancy with mainly sedentary activities, where there is easy access to operable windows and occupants can freely adapt their clothing to the indoor and/or external thermal conditions. This method only applies to spaces where occupants during the majority of their time have metabolic rates ranging from 1,0 met to 1,3 met. It is also important that strict clothing policies inside the building are avoided and that building occupants are free to adapt their clothing to indoor and/or external thermal conditions within a range of at least 0,4 clo to 1,0 clo.

The upper and lower limits presented in ISO 17772-1:2017, Figure H.2 only apply when the running mean external temperature is between 10 °C and 30 °C.

The temperature limits for the summer and the in-between-seasons only apply when the thermal conditions in the spaces at hand are regulated (during those seasons) primarily by the occupants through opening and closing of windows. Several field studies have shown that occupants' thermal responses in such spaces depend in part on the external climate, and differ from the thermal responses of occupants in buildings with mechanical cooling systems, mainly because of differences in thermal experience, presence of adaptive opportunities, differences in perceived control and shifts in occupants' expectations.

For this optional adaptive method to apply, the spaces in question should be equipped with operable windows or comparable facade components which open to the externals and which can be readily opened and adjusted by the occupants of the spaces. These operable windows (facade components) should be designed and positioned in such a way that on warmer days they allow occupants to fine tune the (wind pressure driven) air speeds inside.

There should be no mechanical cooling in operation in the space. Mechanical ventilation with unconditioned air (in summer) can be utilized, but opening and closing of windows should be of primary importance as a means of regulating thermal conditions in the space. In addition, occupants can have additional options for personal control over the indoor environment such as solar shading, fans, shutters, night ventilation, etc.

The spaces can be provided by a heating system, but this optional method does not apply during times of the year when the heating system is in operation.

In residential buildings, the opportunities for (behavioural) adaptation are relatively wide: one is relatively free to adjust metabolism and clothing insulation according to outside weather and momentary indoor temperatures. With an exception for bedrooms where the lower limit should be lower than in other rooms, studies have shown that operative temperature in bedrooms have a significant impact on sleep quality and general health.

Note that the field studies on the temperature limits shown in ISO 17772-1:2017, Annex H do not take work performance effects into account.

In landscaped (open plan) offices most occupants have only limited access to operable windows and therefore typically reduced personal control over natural ventilation, e.g. if there are workplaces placed in the middle of the room, away from direct access to operable windows. Therefore, the temperature limits established by this method will not always apply in such situations.

ISO 17772-1:2017, Figure H.1 includes three categories of temperature limits for use as outlined in the introduction and in ISO 17772-1:2017, Clause 5. The allowable indoor operative temperatures of Figure H.1 are plotted against the running mean external temperature Θ_{rm}.

The following approximate Formula (1) can be used where records of daily mean external temperature are available:

$$\Theta_{\mathrm{rm}} = \frac{(\Theta_{\mathrm{ed}-1} + 0{,}8\Theta_{\mathrm{ed}-2} + 0{,}6\Theta_{\mathrm{ed}-3} + 0{,}5\Theta_{\mathrm{ed}-4} + 0{,}4\Theta_{\mathrm{ed}-5} + 0{,}3\Theta_{\mathrm{ed}-6} + 0{,}2\Theta_{\mathrm{ed}-7})}{3{,}8} \quad (1)$$

The temperature limits presented in ISO 17772-1:2017, Figure H.1 should be used for the dimensioning of passive means to prevent overheating in summer conditions. Some examples are: dimensioning and orientation of windows, dimensioning of solar shading systems and of the thermal capacity of the building. Where the adaptive temperature limits presented in ISO 17772-1:2017, Figure H.1 (upper limits) cannot be guaranteed by passive means, then mechanical cooling should be used. In such cases, the design criteria for buildings with mechanical cooling should be used (see summer limits in ISO 17772-1:2017, H.1).

Note that ISO 17772-1:2017, Figure H.1 already accounts for people's clothing adaptation, therefore, it is not necessary to estimate the clothing values when using the adaptive method presented in ISO 17772-1:2017, H.1. Also, it is normally not required that the following parameters be separately evaluated: local thermal discomfort, clothing insulation, metabolic rate, humidity and air speed.

6.2.4 Increased air velocity

Under summer comfort conditions with indoor operative temperatures >25 °C, increased air velocity can be used to compensate for increased air temperatures. Where there are fans (that can be controlled directly by occupants) or other means for personal air speed adjustment (e.g. personal ventilation systems, or personally operable windows), the upper limits presented in ISO 17772-1:2017, Table H.2 and Figure H.1 can be increased by 2 K to 3 K. The exact temperature correction depends upon the air speed and can be derived from Table B.3 and ISO 17772-1:2017, Table H.2 and Figure H.1. This method can also be used to overcome excessive temperatures in buildings if the local method for controlling air movement (fan, etc.) is available.

Considering the latter: if building occupants have access to fans, personal ventilation systems, personally operable windows, etc. that provide them with precise and step less control over air speed, the upper ISO 17772-1:2017, Table H.4 can be relaxed. The airspeed – temperature offset relation presented in the table is based upon heat transfer from the skin calculations.

The temperature correction by increased air velocity is assumed to be included in the adaptive method for free running buildings, as a prerequisite for this method is that occupants have access to operable windows under their personal control.

For buildings designed using the PMV-PPD approach, the temperature correction can be applied also if occupants have access to operable windows, and not only if the air velocity is provided from fans, etc.

6.3 Design for indoor air quality (ventilation rates)

6.3.1 General

6.3.1.1 Overview

The source control strategy together with ventilation (natural, mechanical and hybrid), placement of air intakes and filtration and air cleaning technologies contribute to improve the indoor air quality. The source control strategy is very important since air pollutants often are generated indoors. For residential buildings, indoor sources will often be the predominant source of air pollutants.

6.3.1.2 Source control

Source control should as often as possible be the primary strategy for controlling the level of air substances. In many cases, the sources will not be known, or little information about emission from building materials and furnishing are known or sources are brought into the space by occupants after the construction of the building. There are several national certification methods for materials that can be used for source control. A local exhaust of a high emitting source (kitchen hood, toilet exhaust, etc.) is also a type of source control.

6.3.1.3 Ventilation

The pollution remaining after source control is dealt with by dilution or displacement with appropriate ventilation air flow rates.

6.3.1.4 Time periods used for determining air flow rates

The methods described in this clause assume that pollutants emissions are constant in each time period considered and lead to a constant design ventilation air flow rate for each time period, therefore it can be a need to look at different time periods with constant values.

6.3.1.5 Building damage

Building damage can occur both at high indoor temperatures (very high room temperatures during warm summer days or if cooling is turned off) or too low temperature due to risk of condensation and resulting mould growth. Therefore, some heating, cooling and/or ventilation could also be needed outside the time of occupancy.

6.3.1.6 Design documentation

The design documents are very important to protect both the designer and the owner. During the lifetime of a building the use and loads can change. It is therefore essential that the original design criteria are documented.

6.3.2 Methods

6.3.2.1 General

6.3.2.1.1 Overview

ISO 17772-1 includes three methods for estimating the design air flow rates, which not necessarily will result in the same indoor air quality. The reason for including many methods is to be open for national preferences in choice of method. Again, it should be clearly stated in the design documents which method was used and why the method was chosen.

6.3.2.2 Method 1 based on perceived air quality

The perceived air quality is basically the odour level in the space perceived by the occupants. As odours will consist of emission from occupants (bio effluents) and emission from building materials and furnishing, Formula (2) is recommended:

$$q_{tot} = n \cdot q_p + A_R \cdot q_B \qquad (2)$$

As we add the odours from people we also have to add the odour from other sources. The knowledge about the people component is relatively well-established[12][13][22][23], while the contribution from other sources is less well-documented. Because of differences in the building component (selection of indoor materials, etc.), the method includes three different building types (see Annex D).

Studies[25][26] have shown that people adapt to the odour from bio effluents, but very little to the emission from building materials and furnishing (reference). This does not mean that adapted persons are not subject to fatigue, impaired concentration, etc. that could follow after exposure to excessive concentration of bioeffluents in air over a longer time. However, the required minimum ventilation of 4 l/s per person apply also for adapted persons. In ISO 17772-1 the perceived air quality levels are set for non-adapted persons. If in special cases the design will be based on adapted persons information is included in C.1.

6.3.2.3 Method 2 using criteria for individual substances

The ventilation rate required to dilute an individual substance (formaldehyde, other VOCs) can be calculated by a simple steady-state mass balance according to Formula (3):

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v} \tag{3}$$

NOTE Different units can be used in the formula (see ISO 17772-1). The ventilation effectiveness can be found from EN 16798-3 and EN 16798-4.

Formula (3) applies to steady-state conditions and the method requires that the external pollutant concentration is lower than the indoor. As indicator for human bioeffluents, the CO_2 concentration is often used. C.3 shows examples calculations using CO_2 as an indicator.

6.3.2.4 Method 3 based on pre-defined ventilation air flow rates

An indirect method of expressing intended indoor air quality is to determine a certain minimum ventilation air flow rate estimated to meet requirement for perceived air quality and health in the occupied zone.

The pre-defined ventilation air flow rates can be expressed by a combination of one or more of the following components: total design ventilation for people and building components (q_{tot}); design ventilation per unit floor area (q_{m^2}); design ventilation per person (q_p); design air change rates (ACH); design opening areas (A_{tot}). Default values are presented in Annex C.

6.3.3 Non-residential buildings

6.3.3.1 Applicable methods

Determining the design ventilation rate is the first step in the process of designing a ventilation system. The design ventilation air flow rates are used for designing any type of ventilation system, including mechanical, natural, hybrid ventilation systems.

6.3.3.2 Ventilation air flow rates during unoccupied periods

To avoid building damage (condensation, mould growth) and too high a level of pollutant concentrations at the start of the occupied hours, it can be necessary to have basic ventilation during unoccupied hours. It is appropriate to use a ventilation rate corresponding to the building component (pollution from the construction materials). Alternatively, full ventilation can be started at a given time before occupation, as described in Annex C.

6.3.4 Residential buildings

6.3.4.1 General

In residential buildings, the occupants can, in most cases, be considered as adapted to the perceived air quality as they occupy the house for a longer time. Unlike other types of buildings, there is no need to maintain a situation where the indoor air quality is perceived as fresh by non-adapted persons entering the building, as this is an unusual situation for everyday use of the residential building. It is, of course, also possible to design the ventilation rate in residential buildings for non-adapted people. The main priority in residential buildings is to ensure a healthy indoor environment, and a secondary priority is to prevent damages to the building from excess of moisture.