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Thermal performance of building components — Dynamic thermal characteristics — Calculation methods

Performance thermique des composants de bâtiment — Caractéristiques thermiques dynamiques — Méthodes de calcul

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Foreword

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

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

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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.

ISO 13786 was prepared by ISO Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 13786:2007), which has been technically revised.

The changes in the third edition are mostly editorial. This document has been re-drafted according to CEN/TS 16629:2014.

This corrected version of ISO 13786 incorporates the following correction:

— In Formula (C.5) the symbol É^2 has been corrected to ω^2.

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Introduction

This document is part of a series aimed at the international harmonization of the methodology for assessing the energy performance of buildings. Throughout, this series is referred to as a "set of EPB standards".

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency.

All EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.

For the correct use of this document, a normative template is given in Annex A to specify these choices. Informative default choices are provided in Annex B.

The main target groups for this document are architects, engineers and regulators.

Use by or for regulators: In case the document is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications. These choices (either the informative default choices from Annex B or choices adapted to national/regional needs, but in any case following the template of Annex A) can be made available as national annex or as separate (e.g. legal) document (national data sheet).

NOTE 1 So in this case:

— the regulators will specify the choices;

— the individual user will apply the document to assess the energy performance of a building, and thereby use the choices made by the regulators.

Topics addressed in this document can be subject to public regulation. Public regulation on the same topics can override the default values in Annex B. Public regulation on the same topics can even, for certain applications, override the use of this document. Legal requirements and choices are in general not published in standards but in legal documents. In order to avoid double publications and difficult updating of double documents, a national annex may refer to the legal texts where national choices have been made by public authorities. Different national annexes or national data sheets are possible, for different applications.

It is expected, if the default values, choices and references to other EPB standards in Annex B are not followed due to national regulations, policy or traditions, that:

— national or regional authorities prepare data sheets containing the choices and national or regional values, according to the model in Annex A. In this case a national annex (e.g. NA) is recommended, containing a reference to these data sheets;

— or, by default, the national standards body will consider the possibility to add or include a national annex in agreement with the template of Annex A, in accordance to the legal documents that give national or regional values and choices.

Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

More information is provided in the Technical Report (ISO/TR 52019-2) accompanying this document.

The subset of EPB standards prepared under the responsibility of ISO/TC 163/SC 2 cover *inter alia*:

— calculation procedures on the overall energy use and energy performance of buildings;

— calculation procedures on the internal temperature in buildings (e.g. in case of no space heating or cooling);

— indicators for partial EPB requirements related to thermal energy balance and fabric features;

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— calculation methods covering the performance and thermal, hygrothermal, solar and visual characteristics of specific parts of the building and specific building elements and components, such as opaque envelope elements, ground floor, windows and facades.

ISO/TC 163/SC 2 cooperates with other technical committees for the details on appliances, technical building systems, indoor environment, etc.

This document provides the means (in part) to assess the contribution that building products and services make to energy conservation and to the overall energy performance of buildings.

This document provides calculation methods for the dynamic thermal characteristics of a building component. These characteristics describe the thermal behaviour of the component when it is subject to variable boundary conditions, i.e. variable heat flow rate or variable temperature on one or both of its boundaries. In this document, only sinusoidal boundary conditions are considered: boundaries are submitted to sinusoidal variations of temperature or heat flow rate.

The properties considered are thermal admittances and thermal dynamic transfer properties, relating cyclic heat flow rate to cyclic temperature variations. Thermal admittance relates heat flow rate to temperature variations on the same side of the component. Thermal dynamic transfer properties relate physical quantities on one side of the component to those on the other side. From the aforementioned properties, it is possible to define the heat capacity of a given component which quantifies the heat storage property of that component.

The dynamic thermal characteristics defined in this document can be used in product specifications of complete building components.

The dynamic thermal characteristics can also be used in the calculation of:

— the internal temperature in a room,

— the daily peak power and energy needs for heating or cooling, and

— the effects of intermittent heating or cooling, etc.

Table 1 shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

NOTE 2 In ISO/TR 52000-2, the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation.

NOTE 3 The modules represent EPB standards, although one EPB standard could cover more than one module and one module could be covered by more than one EPB standard, for instance, a simplified and a detailed method respectively. See also Tables A.1 and B.1.

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Table 1 — Position of this document (*in casu* M2–9) within the modular structure of the set of EPB standards

	Overarching		Building (as such)		Technical building systems									
Sub module	**Descriptions**		**Descriptions**		**Descriptions**	**Heating**	**Cooling**	**Ventilation**	**Humidification**	**Dehumidification**	**Domestic hot water**	**Lighting**	**Building automation and control**	**PV, wind, ..**
sub1		**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
1	General		General		General									
2	Common terms and definitions; symbols, units and subscripts		Building energy needs		Needs								[a]	
3	Applications		(Free) Indoor conditions without systems		Maximum load and power									
4	Ways to express energy performance		Ways to express energy performance		Ways to express energy performance									
5	Building categories and building boundaries		Heat transfer by transmission		Emission and control									
6	Building occupancy and operating conditions		Heat transfer by infiltration and ventilation		Distribution and control									
7	Aggregation of energy services and energy carriers		Internal heat gains		Storage and control									
8	Building zoning		Solar heat gains		Generation and control									
9	Calculated energy performance		Building dynamics (thermal mass)	ISO 13786	Load dispatching and operating conditions									
10	Measured energy performance		Measured energy performance		Measured energy performance									
11	Inspection		Inspection		Inspection									
12	Ways to express indoor comfort				BMS									
13	External environment conditions													
14	Economic calculation													

[a] The shaded modules are not applicable.

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Thermal performance of building components — Dynamic thermal characteristics — Calculation methods

1 Scope

This document specifies the characteristics related to the dynamic thermal behaviour of a complete building component and provides methods for their calculation. It also specifies the information on building materials required for the use of the building component. Since the characteristics depend on the way materials are combined to form building components, this document is not applicable to building materials or to unfinished building components.

The definitions given in this document are applicable to any building component. A simplified calculation method is provided for plane components consisting of plane layers of substantially homogeneous building materials.

Annex C provides simpler methods for the estimation of the heat capacities in some limited cases. These methods are suitable for the determination of dynamic thermal properties required for the estimation of energy consumption. These approximations are not appropriate, however, for product characterization.

NOTE Table 1 in the Introduction shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

2 Normative references

The following documents are referred to in 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 6946, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*

ISO 7345, *Thermal insulation — Physical quantities and definitions*

ISO 10211, *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*

ISO 52000-1:2017, *Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures*

NOTE 1 Default references to EPB standards other than ISO 52000-1 are identified by the EPB module code number and given in Annex A (normative template in Table A.1) and Annex B (informative default choice in Table B.1).

EXAMPLE EPB module code number: M5–5, or M5–5,1 (if module M5–5 is subdivided), or M5–5/1 (if reference to a specific clause of the standard covering M5–5).

NOTE 2 In this document, there are no choices in references to other EPB standards. The sentence and note above is kept to maintain uniformity between all EPB standards.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 52000-1, and the following apply.

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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 http://www.iso.org/obp

3.1 Definitions valid for any component

3.1.1
building element
major part of a building

EXAMPLE Wall, floor or roof.

3.1.2
building component
building element or a part of it

Note 1 to entry: In this document, the word "component" is used to indicate both element and component.

3.1.3
thermal zone of a building
part of a building throughout which the internal temperature is assumed to have negligible spatial variations

Note 1 to entry: A component separates two zones, designated in this document by *m* and *n*.

Note 2 to entry: The external environment can also be considered a zone.

3.1.4
sinusoidal conditions
conditions in which the variations of the temperature and heat flows around their long term average values are described by a sine function of time

Note 1 to entry: Using complex numbers, the temperature in zone *n* can be described by Formula (1) and the heat flow by Formula (2):

$$\theta_n(t) = \bar{\theta}_n + \left|\hat{\theta}_n\right| \times \cos\left(\omega \times t + \psi\right) = \bar{\theta}_n + \frac{1}{2} \times \left[\hat{\theta}_{+n} \times e^{j\omega t} + \hat{\theta}_{-n} \times e^{-j\omega t}\right] \quad (1)$$

$$\Phi_n(t) = \bar{\Phi}_n + \left|\hat{\Phi}_n\right| \times \cos\left(\omega \times \cdot t + \varphi\right) = \bar{\Phi}_n + \frac{1}{2} \times \left[\hat{\Phi}_{+n} \times e^{j\omega t} + \hat{\Phi}_{-n} \times e^{-j\omega t}\right] \quad (2)$$

where

$\bar{\theta}_n$ and $\bar{\Phi}_n$ are average values of temperature and heat flow;

$\left|\hat{\theta}_n\right|$ and $\left|\hat{\Phi}_n\right|$ are amplitudes of temperature and heat flow variations;

$\hat{\theta}_{\pm n}$ and $\hat{\Phi}_{\pm n}$ are complex amplitudes defined by

$$\hat{\theta}_{\pm n} = \left|\hat{\theta}_n\right| e^{\pm j\psi} \quad \text{and} \quad \hat{\Phi}_{\pm n} = \left|\hat{\Phi}_n\right| e^{\pm j\varphi} \quad (3)$$

where ω is the angular frequency of the variations.

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3.1.5
periodic thermal conductance
L_{mn}
complex number relating the periodic heat flow into a component to the periodic temperatures on either side of it under sinusoidal conditions

Note 1 to entry: Another representation of the concept:

$$\hat{\Phi}_m = L_{mm} \times \hat{\theta}_m - L_{mn} \times \hat{\theta}_n \tag{4}$$

Note 2 to entry: L_{mm} relates the periodic heat flow on side *m* to the periodic temperature on side *m* when the temperature amplitude on side *n* is zero. L_{mn} relates the periodic heat flow on side *m* to the periodic temperature on side *n* when the temperature amplitude on side *m* is zero.

Note 3 to entry: As a convention within this document, the heat flow rate is defined as positive when it enters the surface of the component.

3.1.6
heat capacity
modulus of the net periodic thermal conductance divided by the angular frequency

Note 1 to entry: Another representation of the concept:

$$C_m = \frac{1}{\omega} \times \left| L_{mm} - L_{mn} \right| \tag{5}$$

where $\omega = \frac{2\pi}{T}$ and *T* is the period of variation in seconds.

3.1.7
time shift
Δt
period of time between the maximum amplitude of a cause and the maximum amplitude of its effect

3.2 Definitions valid only for one dimensional heat flow

3.2.1
plane component
component for which the smallest curvature radius is at least five times its thickness

3.2.2
homogeneous material layer
layer of material in which the largest size of inhomogenities does not exceed one fifth of the thickness of the layer

3.2.3
thermal admittance
complex quantity defined as the complex amplitude of the density of heat flow rate through the surface of the component adjacent to zone *m*, divided by the complex amplitude of the temperature in the same zone when the temperature on the other side is held constant

Note 1 to entry: Another representation of the concept:

$$Y_{mm} = \frac{\hat{q}_m}{\hat{\theta}_m} \tag{6}$$

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3.2.4
periodic thermal transmittance
complex quantity defined as the complex amplitude of the density of heat flow rate through the surface of the component adjacent to zone *m*, divided by the complex amplitude of the temperature in zone *n* when the temperature in zone *m* is held constant

Note 1 to entry: Another representation of the concept:

$$Y_{mn} = -\frac{\hat{q}_m}{\hat{\theta}_n} \tag{7}$$

3.2.5
areal heat capacity
heat capacity divided by area of element

Note 1 to entry: Another representation of the concept:

$$\kappa_m = \frac{C_m}{A} = \frac{1}{\omega} \times \left| Y_{mm} - Y_{mn} \right| \tag{8}$$

Note 2 to entry: Using Formula (8), the heat capacities are then:

$$C_m = A \times \kappa_m \tag{9}$$

Note 3 to entry: There are two thermal admittances and two heat capacities for a component separating two zones, all of which depend on the period of the thermal variations.

3.2.6
decrement factor
ratio of the modulus of the periodic thermal transmittance to the steady-state thermal transmittance *U*

Note 1 to entry: Another representation of the concept:

$$f = \frac{\left|\hat{q}_m\right|}{\left|\hat{\theta}_n\right| \times U} = \frac{\left|Y_{mn}\right|}{U} \tag{10}$$

where $m \neq n$.

3.2.7
periodic penetration depth
δ
depth at which the amplitude of the temperature variations are reduced by the factor "*e*" in a homogeneous material of infinite thickness subjected to sinusoidal temperature variations on its surface

Note 1 to entry: Another representation of the concept:

$$\delta = \sqrt{\frac{\lambda \times T}{\pi \times \rho \times c}} \tag{11}$$

Note 2 to entry: *e* is the base of natural logarithms; *e* = "2,718..."

3.2.8
heat transfer matrix
Z
matrix relating the complex amplitudes of temperature and heat flow rate on one side of a component to the complex amplitudes of temperature and heat flow rate on the other side

Note 1 to entry: Another representation of the concept:

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$$Z = \begin{pmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} \hat{\theta}_2 \\ \hat{q}_2 \end{pmatrix} = Z \times \begin{pmatrix} \hat{\theta}_1 \\ \hat{q}_1 \end{pmatrix} \tag{12}$$

3.3 Other

3.3.1
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628[3] and CEN/TS 16629[4]

Note 1 to entry: These three basic EPB documents were developed under a mandate given to CEN by the European Commission and the European Free Trade Association and support essential requirements of EU Directive 2010/31/EU on the energy performance of buildings. Several EPB standards and related documents are developed or revised under the same mandate.

[SOURCE: ISO 52000-1:2017, 3.5.14]

4 Symbols and subscripts

4.1 Symbols

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

Symbol	Quantity	Unit
A	area	m^2
C	heat capacity	J/K
L_{mn}	periodic thermal conductance	W/K
R	thermal resistance	$m^2 \cdot K/W$
T	period of the variations	s
U	thermal transmittance under steady-state boundary conditions	$W/(m^2 \cdot K)$
Y_{mm}	thermal admittance	$W/(m^2 \cdot K)$
Y_{mn}	periodic thermal transmittance	$W/(m^2 \cdot K)$
Z	heat transfer matrix environment to environment	—
Z_{mn}	element of the heat transfer matrix	—
a	thermal diffusivity	m^2/s
c	specific heat capacity	$J/(kg \cdot K)$
d	thickness of a layer	m
f	decrement factor	—
j	unit on the imaginary axis for a complex number; $j = \sqrt{-1}$	—
q	density of heat flow rate	W/m^2
t	time	s or h
x	distance through the component	m
Δt	time shift: time lead (if positive), or time lag (if negative)	s or h
δ	periodic penetration depth of a heat wave in a material	m
Φ	heat flow rate	W
ξ	ratio of the thickness of the layer to the penetration depth	—
κ	areal heat capacity	$J/(m^2 \cdot K)$
λ	design thermal conductivity	$W/(m \cdot K)$
ρ	density	kg/m^3

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