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Energy performance of buildings — Sensible and latent heat loads and internal temperatures —

Part 1: Generic calculation procedures

Performance énergétique des bâtiments — Charges thermiques latentes et sensibles et températures intérieures —

Partie 1: Méthodes de calcul génériques

Reference number
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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 52017-1 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 first edition of ISO 52017-1 cancels and replaces ISO 13791:2012, which has been technically revised.

A list of all parts in the ISO 52017 series can be found on the ISO website.

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 accompanying this document (ISO/TR 52016-2[3]) 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;

— 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 TC's for the details on, e.g. appliances, technical building systems and indoor environment.

This document is intended for use by specialists to develop methods for the hourly or subhourly calculation of the internal temperatures and/or the heating, cooling and/or the humidification loads of a thermal zone in a building.

Examples of application of such methods includes the following:

a) assessing the risk of internal overheating;

b) optimizing aspects of building design (building thermal mass, solar protection, ventilation rate, etc.) to provide thermal comfort conditions;

c) assessing whether a building requires mechanical cooling;

d) assessing the energy needs for heating and cooling and for humidification and dehumidification;

e) assessing the sensible heating and cooling and humidification and dehumidification loads under system design conditions.

Criteria for building performance are not included. They can be considered at national level. This document can also be used as a reference to develop more simplified methods for the above and similar applications.

Specific calculation procedures based on the generic calculation procedures of this document are given in ISO 52016-1. The specific simplifications, assumptions and boundary conditions in ISO 52016-1 are tailored to the respective application areas.

The main differences compared to ISO 13791 are the following:

— assumptions or procedures that are not relevant for the generic calculation procedures have been moved to the standard with specific application and combined with other specific assumptions and procedures, for example, specification of the convective heat transfer coefficients;

— the calculation of the operative temperature is added. The solution techniques for the calculation of the operative temperature are not provided in this document, but left up to the specific application standards (e.g. ISO 52016-1);

— the heat flow rates representing the sensible heating and cooling loads and the humidification and dehumidification loads to hold a specific (temperature, moisture) set point are added to the formulae. This widens the application range of the generic calculation procedures without adding complexity. The solution techniques for the calculation of these loads are not provided in this standard, but left up to the specific application standards (e.g. ISO 52016-1), because this is highly application dependent;

— the validation cases have been removed, because there is no need to validate the implementation of the generic calculation method itself. Conformance criteria and deviation allowances highly depend on the application area. Moreover, the reference results of the main validation cases of ISO 13791[1] were questioned and could not be reproduced. Instead, the "BESTEST" test suite, standardized as ANSI/ASHRAE 140[9], comprises a number of test cases that are appropriate for (optional) validation of the calculation methods described in this document. The relevant subset of BESTEST cases is similar to the test cases of ISO 13791. The most relevant BESTEST cases have been adopted in ISO 52016-1 for verification of the specific calculation procedures of that standard.

Relevant editorial changes have been made, based on the detailed technical rules for all EPB standards, including moving all (still relevant) informative annexes to a separate accompanying technical report (ISO/TR 52016-2[3]).

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 In ISO/TR 52000-2[6], 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.

The modules represent EPB standards, although one EPB standard may cover more than one module and one module may be covered by more than one EPB standard, for instance, a simplified and a detailed method respectively. See also Clause 2 and Tables A.1 and B.1.

Table 1 — Position of this document (in casu M2–2, M2–3, M3–3, M4–3, M6–3, M7–3), 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	ISO 52017-1	Needs								a	
3	Applications		(Free) Indoor conditions without systems	ISO 52017-1	Maximum load and power	ISO 52017-1	ISO 52017-1		ISO 52017-1	ISO 52017-1				
4	Ways to express energy performance		Ways to express energy performance		Ways to express energy performance									

a The shaded modules are not applicable

	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**
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)		Load dispatching and operating conditions									
10	Measured energy performance		Measured energy performance		Measured energy performance									

[a] The shaded modules are not applicable

Table 1 *(continued)*

	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
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

Energy performance of buildings — Sensible and latent heat loads and internal temperatures —

Part 1: Generic calculation procedures

1 Scope

This document specifies the general assumptions, boundary conditions and equations for the calculation, under transient hourly or subhourly conditions, of the internal temperatures (air and operative) and/or the heating, cooling and humidification and dehumidification loads to hold a specific (temperature, moisture) set point, in a single building zone. No specific numerical techniques are imposed by this document.

Specific calculation procedures based on the generic calculation procedures of this document are given in ISO 52016-1. The specific simplifications, assumptions and boundary conditions in ISO 52016-1 are tailored to the respective application areas, such as the energy need for heating and cooling and for humidification and dehumidification, hourly internal temperature, design heating and cooling and humidification and dehumidification load.

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 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 7345, *Thermal insulation — Physical quantities and definitions*

ISO 13370, *Thermal performance of buildings — Heat transfer via the ground — Calculation methods*

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

ISO 52010-1, *Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations*

ISO 52016-1, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation 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

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

NOTE The terms of ISO 52000-1 that are indispensable for the understanding of the underlying standard are repeated here.

3.1
building element
wall, roof, ceiling, floor, door or window that separates the internal environment from the external environment or an adjacent space

Note 1 to entry: The definition in ISO 52000-1 reads: "integral component of the technical building systems or of the fabric of a building".

3.2
building thermal zone
thermal zone
internal environment with assumed sufficiently uniform thermal conditions to enable a thermal balance calculation according to the procedures in this document

3.3
design load
maximum hourly mean value of the load, occurring during a design climate period under design use conditions

3.4
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628[5] and CEN/TS 16629[6]

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 (see Reference [7]), and support essential requirements of EU Directive 2010/31/EU on the energy performance of buildings (see Reference [8]). Several EPB standards and related documents are developed or revised under the same mandate.

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

3.5
humidification or dehumidification moisture load
hourly mean value of the water vapour mass flow to be supplied to, or extracted from the internal environment to maintain a specified minimum or maximum humidity within the space

3.6
internal air
air of the internal environment

3.7
internal air temperature
temperature of the air in the internal environment

3.8
internal environment
closed space delimited from the external environment or adjacent spaces by building elements

3.9
internal surface temperature
temperature of the internal surface of a building element

3.10
mean radiant temperature
uniform surface temperature of the internal environment in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure

3.11
operative temperature
uniform temperature of the internal environment in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment

3.12
(sensible) heating or cooling load
hourly mean value of the heating or cooling heat flow rate supplied to or extracted from the internal environment to maintain the intended space temperature conditions

4 Symbols and subscripts

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52000-1, Clause 4 and Annex C and the following apply.

Symbol	Quantity	Unit
A	area	m^2
a	thermal diffusivity	m^2/s
C	heat capacity	J/K
c	specific heat capacity	J/(kg·K)
c	coefficient	various
d	thickness	m
E_r	ventilation parameter	—
F	view factor	—
f	factor	—
f	fraction	—
G	moisture flow	kg/s
g_s	heat flow rate per volume	W/m^3
g	acceleration due to gravity	m/s^2
H	heat transfer coefficient	W/K
h	surface coefficient of heat transfer	$W/(m^2·K)$
h	latent heat	J/kg
I	irradiance	W/m^2
J	radiosity	W/m^2
l	length	M
m	mass flow rate	kg/s
p	pressure	Pa
q	heat flow density	W/m^2
q_V	air volume flow rate	m^3/h
R	thermal resistance	$m^2·K/W$

Symbol	Quantity	Unit
T	thermodynamic temperature	K
t	time	s
U	thermal transmittance	$W/(m^2 \cdot K)$
V	volume	m^3
v	velocity	m/s
x	moisture content or mixing ratio	kg/kg(dry air)
x, y, z	coordinates	m
Λ	thermal conductance	$W/(m^2 \cdot K)$
Φ	heat flow rate	W
α	absorptance	—
ε	emissivity	—
θ	Celsius temperature	°C
λ	thermal conductivity	$W/(m \cdot K)$
μ	viscosity	$kg/(m \cdot s)$
ν	humidity by volume	kg/m^3
σ	Stefan-Boltzmann constant, $5{,}670 \times 10^{-8}$	$W/(m^2 \cdot K^4)$
ρ	reflectance	—
ρ	density	kg/m^3
χ	point thermal transmittance	W/K
Ψ	linear thermal transmittance	$W/(m \cdot K)$

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52000-1, Clause 4 and Annex C and the following apply.

Subscript	Term	Subscript	Term	Subscript	Term
a	air	i	internal	s	sunlit
b	building	i	internal sources	sens	sensible
c	convection, convective	*i,j,k*	indexes	sol	solar
c	contact with air layer	in	entering, inlet	sa	solar to air
C	cooling[a]	int	internal	sh	shaded
cd	conduction	lat	latent	sk	sky
DHU	dehumidification[a]	ld	load	sl	solar loss
dif	diffuse	lr	long-wave radiation	sup	supply
dir	direct	m	mechanical ventilation	th	thermal
d	distribution	me	medium	t	time
d	discharge	mr	mean radiant	tb	thermal bridge
e	external or outdoor	n	normal to surface	T	thermal[a]
eq	equivalent	nd	need	V	ventilation
f	floor	op	operative	v	velocity

[a] Type of energy use.

Subscript	Term	Subscript	Term	Subscript	Term
g	ground	p	projected	w	wind
H	heating[a]	r	radiation	we	water evaporation
HU	humidification[a]	s	surface	X	humidification and dehumidification[a]
[a] Type of energy use.					

5 Brief description of the method

5.1 Output of the method

This method covers the generic methodology for the transient calculation of the internal thermal balance in a building. This method can be used to calculate the time series of the internal temperature and the sensible and latent heat loads.

The time interval of the output is hourly or subhourly.

5.2 General description of the method

The evaluation of the time series of internal temperature, sensible and/or latent heat loads of a building or building thermal zone involves the solution of a system of equations for the transient heat and mass transfers between the external and internal environment through the opaque and transparent elements bounding the building or thermal zone envelope, as a function of internal and external heat flow, temperature and moisture conditions.

6 Calculation method

6.1 Output data

The output data of this method are listed in Table 2. It depends on the application which data are input and which data are output.

Table 2 — Output data of this method; time series, calculated quantities

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
In case the sensible heating and cooling load is given as input or equals zero:					
Indoor air temperature	$\theta_{int;a}$	°C	0 to 50	N.A.[d]	YES
Internal surface temperature of each building element	θ_{s}	°C	0 to 50	N.A.[d]	YES
Mean radiant temperature	$\theta_{int;mr}$	°C	0 to 50	N.A.[d]	YES

NOTE For example, the EPB standards under the EPB modules M2–2 and M2–3 are based on this reference calculation procedure and produce output for other EPB modules.

[a] Practical range, informative.

[b] Informative.

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] EPB module. Not applicable in this document because this is a reference calculation procedure.

Table 2 *(continued)*

Description	Symbol	Unit	Validity interval[a]	Intended destination module[b]	Varying[c]
Operative temperature	$\theta_{int;op}$	°C	0 to 50	N.A.[d]	YES
In case internal moisture production and moisture supply are given as input or equal zero:					
Moisture content	$x_{int;a}$	kg_{H2O}/kg (dry air)	0 to ∞	N.A.[d]	YES
In case indoor temperature set points are given:					
(Sensible) heating and cooling load	$\Phi_{HC;ld}$	W	-∞ to ∞	N.A.[d]	YES
In case indoor moisture set points are given:					
humidification and dehumidification moisture load	$G_{(D)HU;ld}$	kg_{H2O}/s	-∞ to ∞	N.A.[d]	YES

NOTE For example, the EPB standards under the EPB modules M2–2 and M2–3 are based on this reference calculation procedure and produce output for other EPB modules.

[a] Practical range, informative.

[b] Informative.

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] EPB module. Not applicable in this document because this is a reference calculation procedure.

6.2 Calculation time interval and calculation period

The method in this document is suitable for an hourly or subhourly time interval.

The length of the calculation period depends on the application.

6.3 Input data

The method in this document is a generic method intended for use by specialists to develop and/or validate methods for the hourly or subhourly calculation of the internal temperature.

The input data for this method are listed in Table 3. It depends on the application which data are input and which data are output.

Table 3 — Input data for this method; time series

Name	Symbol	Unit	Validity interval[a]	Origin[b]	Varying[c]
In case the loads are the output:					
Operative temperature (e.g. set points)	$\theta_{int;op}$	°C	0 to 50	N.A.[d]	YES
Moisture content (e.g. set points)	$x_{int;a}$	kg_{H2O}/kg (dry air)	0 to ∞	N.A.[d]	YES

[a] Practical range, informative.

[b] For instance, EPB module or (e.g. product) standard or “local” (type, geometry).

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] The details are given in the application standards, such as ISO 52016-1.

Table 3 *(continued)*

Name	Symbol	Unit	Validity interval[a]	Origin[b]	Varying[c]
In case the internal temperature resp. moisture content are the output:					
(Sensible) heating and cooling load	$\Phi_{HC;ld}$	W	-∞ to ∞	N.A.[d]	YES
humidification and dehumidification moisture load	$G_{(D)HU;ld}$	kg_{H20}/s	-∞ to ∞	N.A.[d]	YES
General:					
Geometrical data	See 6.4. Because the calculation procedures are generic, these input data cannot be specified in detail[d].				
Thermo-physical parameters of the building and building elements	See 6.4. Because the calculation procedures are generic, these input data cannot be specified in detail[d].				
Operating and boundary conditions	See 6.4. Because the calculation procedures are generic, these input data cannot be specified in detail[d].				
Constants and physical data	See 6.4. Because the calculation procedures are generic, these input data cannot be specified in detail[d].				

[a] Practical range, informative.

[b] For instance, EPB module or (e.g. product) standard or “local” (type, geometry).

[c] “Varying”: value may vary over time: different values per time interval, for instance: hourly values or monthly values (not constant values over the year).

[d] The details are given in the application standards, such as ISO 52016-1.

Hourly climatic data shall be obtained from ISO 52010-1.

6.4 Calculation procedure

6.4.1 Applicable time interval

This procedure can be used with an hourly or subhourly time interval.

6.4.2 Assumptions

General assumptions for the calculation of the internal temperatures are the following:

— the air temperature is uniform throughout the building zone;

— the various surfaces of the building elements are isothermal;

— the heat conduction through the building elements (excluding to the ground) is assumed to be one-dimensional;

— the heat conduction to the ground through building elements is treated by an equivalent one-dimensional heat flow rate according to ISO 13370;

— the heat storage contribution of (linear or point) thermal bridges is neglected;

— (linear or point) thermal bridges are directly thermally coupled to the internal and outdoor air temperatures;

— air spaces are treated as air layers bounded by two isothermal and parallel surfaces;

— the heat storage effects in the various planes of a glazed element are neglected;

— the density of heat flow rate due to the short-wave radiation absorbed by each plane of a glazed element is treated as a source term.

6.4.3 Calculation of relevant temperatures

6.4.3.1 Operative temperature

The internal operative temperature is calculated according to Formula (1):

$$\theta_{\text{int;op}} = f_{\text{a}} \cdot \theta_{\text{int;a}} + \left(1 - f_{\text{a}}\right) \cdot \theta_{\text{int;mr}} \tag{1}$$

where

$\theta_{\text{int;op}}$ is the internal operative temperature, in °C;

f_{a} is the fraction that the air temperature contributes to the operative temperature;

$\theta_{\text{int;a}}$ is the temperature of the internal air, calculated according to 6.4.3.2, in °C;

$\theta_{\text{int;mr}}$ is the internal mean radiant temperature, the weighted average of internal surface temperatures, in °C, calculated according to Formula (2):

$$\theta_{\text{int;mr}} = \frac{\sum_j \left(A_j \cdot \theta_{\text{s},j}\right)}{\sum_j A_j} \tag{2}$$

where

$\theta_{\text{s},j}$ is the internal surface temperature of building element j, calculated according to 6.4.3.3, in °C;

A_j is the area of building element j, in m^2.

6.4.3.2 Sensible heat balance equation and internal air temperature

The internal air temperature in a building or building zone, at any given time, is obtained by solving Formula (3), where heat flow rates to the internal air are taken as positive:

$$\sum_{j=1}^{N} \left(A \cdot q_{\text{c;i}}\right)_j + \Phi_{\text{V}} + \Phi_{\text{int;c}} + \Phi_{\text{HC;ld;c}} + \Phi_{\text{sa}} + \Phi_{\text{va}} + \Phi_{\text{tb}} = c_{\text{a}} \cdot \rho_{\text{int;a}} \cdot V_{\text{int;a}} \cdot \frac{\text{d}\theta_{\text{int;a}}}{\text{d}t} \tag{3}$$

where

N is the number of internal surfaces delimiting the internal air;

A_j is the area of building element j, in m^2;

$q_{\text{c;i}}$ is the density of the heat flow rate by convection at the internal surface, obtained in accordance with 6.4.5.2.2, in W/m^2;

Φ_{V} is the heat flow rate by ventilation, obtained in accordance with 6.4.5.7, in W;

$\Phi_{\text{int;c}}$ is the convective fraction of heat flow rate due to internal sources, obtained in accordance with 6.4.5.6, in W;

$\Phi_{HC;ld;c}$ is the convective part of heat flow rate due to sensible space heating or cooling loads, obtained in accordance with 6.4.5.7, in W;

Φ_{sa} is the solar to air heat flow rate, obtained in accordance with 6.4.5.4.4, in W;

Φ_{va} is the heat flow rate due to the air entering the building zone through air layers within the elements bounding the zone, obtained in accordance with 6.4.5.2.4, in W;

Φ_{tb} is the heat flow rate due to thermal bridges in accordance with 6.4.5.3, in W;

c_a is the specific heat capacity of air, in J/(kg·K);

$\rho_{int;a}$ is the density of the internal dry air, in kg/m^3;

$V_{int;a}$ is the volume of the internal air, in m^3;

$\theta_{int;a}$ is the temperature of the internal air, in °C;

t is the time, in s.

NOTE Because of the very small value of the term (ρ_a $V_{int;a}$), the right-hand side of Formula (3) can be assumed to be zero, unless, by approximation, other materials are included in this term (e.g. furniture and/or lightweight internal partitions).

Alternatively, specific solution techniques can be applied to calculate the (sensible) heating or cooling load under given intended space temperature conditions (see 6.4.4).

6.4.3.3 Internal surface temperature

The internal surface temperature of building element j is obtained by solving Formula (4), where heat flow rates to the internal surface, except $q_{c,j}$, are taken as positive:

$$q_{lr,j} + q_{sol,j} + q_{c,j} + q_{cd,j} + q_{i;r} + q_{HC;ld;r} = 0 \tag{4}$$

where

q_{lr} is the density of the heat flow rate due to long-wave radiation exchanged with other internal surfaces, obtained in accordance with 6.4.5.5.2, in W/m^2;

q_{sol} is the density of the heat flow rate due to the absorbed (short-wave) solar radiation, obtained in accordance with 6.4.5.4, in W/m^2;

q_c is the density of the heat flow rate released to the building zone air by convection, obtained in accordance with 6.4.5.2.2, in W/m^2;

q_{cd} is the density of the heat flow rate by conduction, obtained in accordance with 6.4.5.1, in W/m^2;

$q_{i;r}$ is the density of the heat flow rate due to the radiative component of internal gains, calculated according to Formula (6), in W/m^2;

$q_{HC;ld;r}$ is the density of the heat flow rate due to the radiative component of the sensible space heating or cooling load, calculated according to Formula (6), in W/m^2.

The density of heat flow rate due to the radiative component of internal gains and space heating and cooling load are given by Formulae (5) and (6), respectively:

$$q_{\mathrm{i;r}} = \frac{\Phi_{\mathrm{int;r}}}{\sum_{j=1}^{N} A_j} \tag{5}$$

$$q_{\mathrm{HC;ld;r}} = \frac{\Phi_{\mathrm{HC;ld;r}}}{\sum_{j=1}^{N} A_j} \tag{6}$$

where

$\Phi_{\mathrm{int;r}}$ is the radiative fraction of heat flow rate due to internal sources, obtained in accordance with 6.4.5.6, in W;

N is the number of surfaces delimiting the internal air;

A_j is the area of building element j, in m^2;

$\Phi_{\mathrm{HC;ld;r}}$ is the heat flow rate due to the radiative component of sensible space heating or cooling loads, obtained in accordance with 6.4.5.7, in W.

6.4.3.4 Temperature of surface delimiting two solid layers

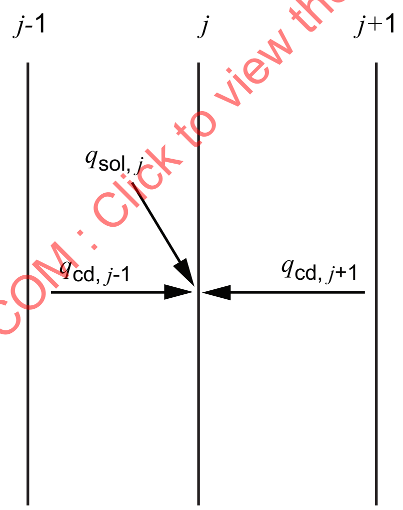


Figure 1 — Surface delimiting two layers

The temperature at surface j delimiting two layers in an element, shown in Figure 1, is obtained by solving Formula (7):

$$q_{\mathrm{cd},j-1} + q_{\mathrm{cd},j+1} + q_{\mathrm{sr},j} = 0 \tag{7}$$

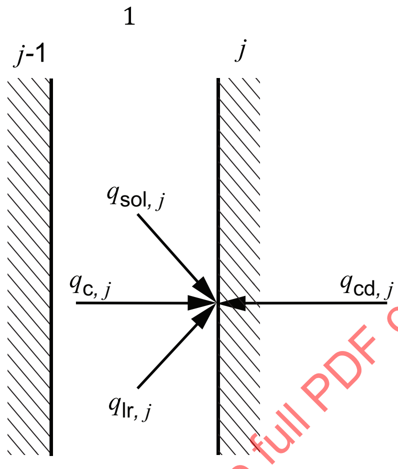
where

$q_{cd,j-1}$ is the density of the heat flow rate by conduction from the j–1 surface, obtained in accordance with 6.4.5.1, in W/m²;

$q_{cd,j+1}$ is the density of the heat flow rate by conduction from the j+1 surface, obtained in accordance with 6.4.5.1, in W/m²;

$q_{sol,j}$ is the density of the heat flow rate due to the (short wave) solar radiation absorbed by the surface j, obtained in accordance with 6.4.5.4, in W/m².

6.4.3.5 Temperature of surface of an air layer



Key

1 air layer

Figure 2 — Surface delimiting an air layer

The temperature at surface j of an air layer shown in Figure 2 is obtained by solving Formula (8):

$$q_{c,j} + q_{lr,j} + q_{cd,j} + q_{sol,j} = 0 \quad (8)$$

where

q_c is the density of the total heat flow rate released to the air layer, obtained in accordance with 6.4.5.2, in W/m²;

q_{lr} is the density of the heat flow rate received by long-wave radiation across the air layer, obtained in accordance with 6.4.5.5, in W/m²;

q_{cd} is the density of the heat flow rate by conduction, obtained in accordance with 6.4.5.1, in W/m²;

q_{sol} is the density of the heat flow rate absorbed due to solar radiation (or another external source of short-wave radiation), obtained in accordance with 6.4.5.4, in W/m².

6.4.3.6 Temperature of external surface of a building element

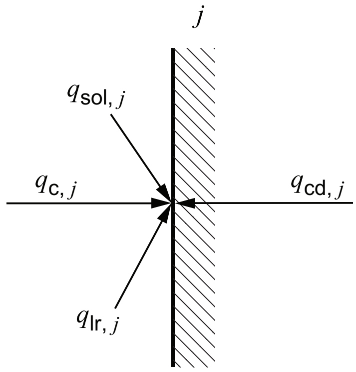


Figure 3 — External surface of an element

The temperature at surface *j* of a building element, shown in Figure 3, is obtained by solving Formula (9):

$$q_{\text{lr},j} + q_{\text{sol},j} + q_{\text{c},j} + q_{\text{cd},j} = 0 \tag{9}$$

where

q_{lr} is the density of the heat flow rate by long-wave radiation at the surface, obtained in accordance with 6.4.5.5.1, in W/m²;

q_{sol} is the density of the heat flow rate due to the (short-wave) solar radiation absorbed by the surface, obtained in accordance with 6.4.5.4, in W/m²;

q_{c} is the density of the heat flow rate by convection with the air, obtained in accordance with 6.4.5.2.2, in W/m²;

q_{cd} is the density of the heat flow rate by conduction, obtained in accordance with 6.4.5.1, in W/m².

6.4.4 Building zone thermal balance (sensible heat)

In each formula of 6.4.3, the time-dependent heat flow rates shall be expressed in terms of operators which relate the heat flow rate at the internal surface of each element to the temperature at the internal and external surface, and that of the internal air, by using suitable mathematical models of the heat transfer processes.

The temperature of the internal air, together with the temperature of the different surfaces, shall be determined by solving the global equation system at each time interval considered.

A general expression of the formula system is given in Formula (10):

$$\begin{pmatrix} \Pi_{1,1} & \Pi_{1,2} & \Pi_{1,N} & \Pi_{1,N+1} \\ \Pi_{2,1} & \Pi_{2,2} & \Pi_{2,N} & \Pi_{2,N+1} \\ \Pi_{N,1} & \Pi_{N,2} & \Pi_{N,N} & \Pi_{N,N+1} \\ \Pi_{N+1,1} & \Pi_{N+1,2} & \Pi_{N+1,N} & \Pi_{N+1,N+1} \end{pmatrix} \begin{pmatrix} \theta_{\text{is},1} \\ \theta_{\text{is},2} \\ \theta_{\text{is},N} \\ \theta_{\text{a}} \end{pmatrix} = \begin{pmatrix} \Gamma_1 \\ \Gamma_2 \\ \Gamma_N \\ \Gamma_{N+1} \end{pmatrix} \tag{10}$$

where

N is the number of elements bounding the building zone corresponding to the internal surfaces delimiting the internal air;

Π are the coefficients of the unknown temperatures (θ) (from 1 to N relating to the internal surfaces, $N + 1$ relating to the internal air);

Γ are the coefficients of the known terms (from 1 to N relating to the internal surfaces, $N + 1$ relating to the internal air);

θ are the unknown temperatures (from 1 to N relating to the internal surfaces, $N + 1$ relating to the internal air).

The "Π" and "Γ" terms are obtained by rewriting Formulae (3), (4), (7) or Formulae (8) and (9) in order to separate the unknown parameters from the known parameters.

The unknown parameters are the air temperature at the given time t for Formula (3) and the internal, external and inside surface temperatures for each component at the given time t for the other formulae. The form of these formulae depends on the solution technique adopted.

Alternatively, other or additional solution techniques can be applied to calculate the (sensible) heating or cooling load under given intended space temperature conditions.

6.4.5 Heat transfer components

6.4.5.1 Heat conduction through components

For elements with constant thermal conductivity and specific heat capacity, the density of heat flow by conduction is governed by Formulae (11) and (12):

$$q_{\text{cd;n}} = -\lambda \cdot \left(\frac{\partial \theta}{\partial n} \right) \tag{11}$$

$$\lambda \cdot \left(\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2} \right) + g = c_{\text{me}} \cdot \rho_{\text{me}} \cdot \frac{\text{d}\theta}{\text{d}t} \tag{12}$$

where

$q_{\text{cd;n}}$ is the density of heat flow rate in direction n, in W/m²;

θ is the temperature of the component (in direction of the heat flow) at time t, in °C;

λ is the thermal conductivity of the medium, in W/(m·K);

c_{me} is the specific heat capacity of the medium, in J/(kg·K);

ρ_{me} is the density of the medium, in kg/m³;

g is the heat source term (heat flow rate per volume), in W/m³;

x,y,z are the coordinates.

These formulae can be solved by any appropriate procedure which provides results in accordance with the validation procedure given in 7.2.

In case of (assumed) one-dimensional heat flow, perpendicular through each building element (coordinate x), the second derivatives to coordinates y and z in Formula (12) are omitted.

6.4.5.2 Convective heat transfer

6.4.5.2.1 General

Convective heat transfer occurs at the boundary surfaces of each building element and through air layers.

6.4.5.2.2 Convective heat flow rate at the surface of an element

The density of the convective heat flow rate at the internal and external surface of an element, q_c, is given by Formula (13):

$$q_c = h_c \cdot (\theta_s - \theta_a) \tag{13}$$

where

- q_c is the convective heat flow rate at the surface, in W/m^2;
- h_c is the convective heat transfer coefficient of the surface, in W/(m^2·K);
- θ_s is the surface temperature, for internal surfaces obtained in accordance with 6.4.3.3 and for external surfaces obtained in accordance with 6.4.3.6, in °C;
- θ_a is the air temperature of the internal or external environment, in °C.

6.4.5.2.3 Convective heat transfer through unventilated air layers

The density of the convective heat flow rate through an unventilated air layer, q_c, is given by Formula (14):

$$q_c = \Lambda_a \cdot \Delta\theta \tag{14}$$

where

- q_c is the density of the heat flow rate by convection, in W/m^2;
- $\Delta\theta$ is the temperature difference between the surfaces delimiting the layer, in K;
- Λ_a is the thermal conductance of the air layer, in W/(m·K).

6.4.5.2.4 Convective heat transfer through ventilated air layer

The convective heat flow rate through a ventilated air layer, Φ_{va}, depends on the air flow rate in the air layer. The heat flow rates to be considered are:

a) the convective heat flow rate, Φ_{va}, due to air passing through the air layer and into the zone, given by Formula (15):

$$\Phi_{va} = m_{a;v} \cdot c_a \cdot (\theta_l - \theta_{int;a}) \tag{15}$$

where

Φ_{va} is the convective heat flow rate, in W;

$m_{a;v}$ is the mass air flow through the air layer, in kg/s;

c_a is the specific heat capacity of air, in J/(kg·K);

θ_l is the temperature of the air leaving the layer, in °C.

b) the convective heat flow rate, $\Phi_{c,j}$, between surfaces and air, given by Formula (16):

$$\Phi_{c,j} = h_a \cdot A_c \cdot \left(\theta_j - \theta_{eq}\right)$$

$$\Phi_{c,j+1} = h_a \cdot A_c \cdot \left(\theta_{j+1} - \theta_{eq}\right) \tag{16}$$

where

A_c is the area of the surface in contact with the air layer, in m²;

h_a is the convective heat transfer coefficient for ventilated layers, in W/m²;

θ_{eq} is the equivalent temperature of the air in the layer, in °C;

j and $j + 1$ are the surfaces delimiting the air layer.

6.4.5.3 Thermal bridges

Linear and point thermal bridges are assumed to have no thermal capacity. The density of heat flow rate due to thermal bridges is obtained by Formula (17):

$$\Phi_{tb} = H_{tb} \cdot \left(\theta_l - \theta_{e;a}\right) \tag{17}$$

with

$$H_{tb} = \sum_k \left(l_k \cdot \Psi_k\right) + \sum_j \chi_j \tag{18}$$

where

l_k is the length of linear thermal bridge k, in m;

Ψ_k is the linear thermal transmittance of thermal bridge k, in W/(m·K);

χ_j is the point thermal transmittance of point thermal bridge j, in W/K.

6.4.5.4 Short-wave radiation heat transfers

6.4.5.4.1 Short-wave radiation heat transfer at the external surface of opaque element

The density of short-wave radiation heat flow rate at the external surface of an opaque element is given by Formula (19):

$$q_{sol;e} = \alpha_{sol} \cdot \left(f_s \cdot I_{dir} + I_{dif}\right) \tag{19}$$

where

$q_{sol;e}$ is the density of (short-wave) solar (and/or other short-wave) radiation heat flow rate at the external surface of an opaque element, in W/m^2;

α_{sol} is the solar absorptance of the external surface;

f_s is the sunlit factor;

I_{dir} is the direct component of the solar radiation reaching the surface, in W/m^2;

I_{dif} is the diffuse component of the solar radiation reaching the surface, in W/m^2.

The values of solar absorptance of external opaque surfaces, α_{sol}, depend on the characteristics of the external surface of the element.

The sunlit factor, f_s, is given by Formula (20):

$$f_s = \frac{A_s}{A} \quad (20)$$

where

A_s is the sunlit area of the wall (defined in 6.4.5.4.5), in m^2;

A is the total area of the wall, in m^2.

6.4.5.4.2 Short-wave radiation heat transfer at the internal surface of opaque elements

The density of heat flow rate by (short-wave) solar radiation absorbed at the internal surface of an opaque element is given by Formula (21):

$$q_{sol;int} = f_d \cdot \frac{\left(1 - f_{sa}\right) \cdot \left(1 - f_{sl}\right) \cdot \left(\Phi_{sol;dir} + \Phi_{sol;dif}\right)}{A} \quad (21)$$

where

$q_{sol;int}$ is the density of (short-wave) solar radiation heat flow rate at the internal surface of an opaque element, in W/m^2;

f_d is the distribution factor of the solar radiation at the internal surface of the element;

f_{sa} is the solar to air factor of the zone;

f_{sl} is the solar loss factor of the zone;

$\Phi_{sol;dir}$ is the heat flow rate due to the direct component of solar radiation entering the zone, calculated according to Formula (22), in W;

$\Phi_{sol;dif}$ is the heat flow rate due to the diffuse component of solar radiation entering the zone, calculated according to Formula (23), in W;

A is the area of the opaque element, in m^2.

The heat flow rates due to the direct and diffuse components of the solar radiation entering the zone are given by Formulae (22) and (23), respectively:

$$\Phi_{sol;dir} = \sum_{j=1}^{J} \left(I_{dir} \cdot \tau_{dir} \cdot A_s\right)_j \quad (22)$$

$$\Phi_{\text{sol;dif}} = \sum_{j=1}^{J} \left(I_{\text{dif}} \cdot \tau_{\text{dif}} \cdot A \right)_j \tag{23}$$

where

J	is the number of glazing systems;
I_{dir}	is the direct component of solar radiation reaching the external surface of the system j, in W/m^2;
I_{dif}	is the diffuse component of solar radiation reaching the external surface of the glazing system j, in W/m^2;
τ_{dir}	is the direct solar transmittance of the glazing system;
τ_{dif}	is the diffuse solar transmittance of the glazing system;
A_{s}	is the sunlit area of the glazing, in m^2;
A	is the glazing area, in m^2.

Solar to air factor

The solar to air factor, f_{sa}, is the fraction of solar heat entering the zone through the glazing which is immediately transferred to the internal air. This fraction depends on the quantity of internal items with very low thermal capacity such as carpets and furniture. It is assumed to be time-independent.

Solar loss factor

The solar loss factor, f_{sl}, is the fraction of the solar radiation entering the zone which is reflected back to the external environment. It depends on the geometrical characteristics and solar properties of the glazing system, the exposure of the glazing, the solar angles and the zone geometry and colour of the surfaces. It is assumed to be time-independent.

Distribution factors

The distribution factors, f_{d}, define the amount of the direct solar radiation absorbed per area at the different internal surfaces of the walls, ceiling, floor, etc. They depend on the solar angles, the geometrical dimensions of glazing and zone, the short-wave reflectance of components, and the furniture and furnishings. It is assumed to be time-independent.

A simple approximation of the distribution factor is the area of the internal surface of the element divided by the sum of areas of the internal surfaces of all elements.

6.4.5.4.3 Short-wave radiation heat flow rate for transparent elements (including blinds and curtains)

The density of heat flow rate for element j of the glazing system due to the absorbed solar radiation shall be calculated according to Formula (24):

$$q_{\text{sol},j} = \alpha'_{\text{sol},j} \cdot \left(I_{\text{dir}} \cdot f_{\text{s}} + I_{\text{dif}} \right) \tag{24}$$

where

$q_{sol,j}$ is the density of (short-wave) solar radiation heat flow rate for element j of the glazing system, in W/m^2;

j is the element of the glazing system;

α'_{sol} is the equivalent solar absorptance;

I_{dir} is the direct component of solar radiation reaching the external surface of the system j, in W/m^2;

f_s is the sunlit factor;

I_{dif} is the diffuse component of solar radiation reaching the external surface of the glazing system j, in W/m^2.

If curtains or venetian blinds are present, the following situations can occur:

a) curtain/blind completely closed;

b) curtain/blind not completely closed.

In case a), the glazing component and the curtain/blind are treated as a single envelope component having appropriate solar coefficients.

In case b), two different components shall be considered:

— the portion of glazing area not covered by the curtain/blind, comprising the glazing component only;

— the portion of glazing area covered by the curtain/blind, treated as in case a).

6.4.5.4.4 Solar to air heat flow rate

The solar to air heat flow rate, Φ_{sa}, is the heat flow rate due to solar radiation, entering through the glazing system, directly transferred to the internal air. It is given by Formula (25):

$$\Phi_{sa} = f_{sa} \cdot \left(1 - f_{sl}\right) \cdot \left(\Phi_{sol;dir} + \Phi_{sol;dif}\right) \quad (25)$$

where

Φ_{sa} is the solar to air heat flow rate, in W;

f_{sa} is the solar to air factor of the zone;

f_{sl} is the solar loss factor of the zone;

$\Phi_{sol;dir}$ is the heat flow rate due to the direct component of solar radiation entering the zone, calculated according to Formula (22), in W;

$\Phi_{sol;dif}$ is the heat flow rate due to the diffuse component of solar radiation entering the zone, calculated according to Formula (23), in W.

Solar to air factor

The solar to air factor, f_{sa}, is the fraction of solar heat entering the room through the glazing which is immediately transferred to the internal air. This fraction depends on the quantity of internal items with very low thermal capacity such as carpets and furniture. It is assumed to be time-independent.

Solar loss factor

The solar loss factor, f_{sl}, is the fraction of the solar radiation entering the room which is reflected back to the external environment. It depends on the geometrical characteristics and solar properties of the glazing system, the exposure of the glazing, the solar angles and the room geometry and colour of the surfaces. It is assumed to be time-independent.

NOTE Typical values are given in ISO/TR 52016-2[3].

6.4.5.4.5 Sunlit area of room element

When external obstructions are present, the area of an element can be partially shaded. Obstructions considered in this document are: horizontal overhangs, side fins, window set back and surrounding constructions. A sunlit factor is defined in Formula (20) and may be added for the diffuse radiation in Formulae (19) and (24).

6.4.5.5 Long-wave radiation heat transfer

6.4.5.5.1 Long-wave radiative heat flow rate at the external surface

The density of the net long-wave radiant heat flow rate received by an external surface, q_{lr}, is given by Formula (26):

$$q_{lr} = h_{lr} \cdot \left(\theta_{e;a} - \theta_{s;e}\right) - q_{sk} \tag{26}$$

where

q_{lr} is the density of the net long-wave radiant heat flow rate received by an external surface, in W/m^2;

h_{lr} is the long-wave radiative heat transfer coefficient, calculated according to Formula (27), in W/(m^2·K);

$\theta_{e;a}$ is the external air temperature, in °C;

$\theta_{s;e}$ is the external surface temperature, in °C;

q_{sk} is the correction for the long-wave radiation exchanges from the wall to the sky, calculated according to Formula (29), in W/m^2.

Using thermodynamic temperatures ($T = \theta + 273{,}15$), the value of h_{lr} is approximated by Formula (27):

$$h_{lr} = 4 \cdot \varepsilon \cdot \sigma \left(\frac{T_{e;a} + T_{s;e}}{2}\right)^3 \tag{27}$$

where

ε is the long-wave emissivity of the surface;

σ is the Stefan-Boltzmann constant: 5,67 × 10^{-8} W/(m^2·K^4);

$T_{e;a}$ is the external air temperature, in K;

$T_{s;e}$ is the surface temperature, in K.

The calculations shall be made with a fixed value of h_{lr}.

EXAMPLE The terms of Formula (27) can be calculated with the following conditions:

— emissivity of the external surface $\varepsilon = 0{,}93$;

— reference temperature 283 (293) K.

Under these conditions, the value of h_{lr}, for external surfaces, is 4,8 W/(m²·K).

The correction for the long-wave radiation emitted from the element to the sky, q_{sk}, is given by Formula (28):

$$q_{sk} = F_{sk} \cdot 4 \cdot \varepsilon \cdot \sigma \cdot \left(\frac{T_{e;a} + T_{sk}}{2} \right)^3 \cdot \left(T_{e;a} - T_{sk} \right) \quad (28)$$

where

F_{sk} is the view factor from building element j to the sky (solid angle divided by 2π);

$T_{e;a}$ is the external air temperature, in K;

T_{sk} is the temperature of the sky, in K.

The temperature of the sky depends on the characteristics of the atmosphere and its vapour content.

NOTE Typical values are given in ISO/TR 52016-2[3].

6.4.5.5.2 Long-wave radiative heat flow rate at the internal surface

The density of net long-wave radiant heat flow rate, q_{lr}, received by the internal surface j, is given by Formula (29):

$$q_{lr,j} = \sum_{k=1}^{N} \left(F_{j,k} \cdot J_{lr,k} \right) - J_{lr,j} \quad (29)$$

where

q_{lr} is the density of the net long-wave radiant heat flow rate received by the internal surface j, in W/m²;

N is the number of internal surfaces delimiting the internal air;

$F_{j,k}$ is the view factor from surface j to surface k;

$J_{lr,j}$ is the long-wave radiosity of the surface j, calculated according to Formula (30), in W/m²;

$J_{lr,k}$ is the long-wave radiosity of the surface k, calculated according to Formula (30) in W/m².

The long-wave radiosity of a surface is the total density of heat flow rate emitted and reflected by this surface, all surfaces being here considered as grey bodies. Thus, the long-wave radiosity of surface j is shown in Formula (30):

$$J_{lr,j} = \rho_j \cdot \sum_{k=1}^{N} \left(F_{j,k} \cdot J_{lr,k} \right) + \varepsilon_j \cdot \sigma \cdot T_j^{\,4} \quad (30)$$

where

$J_{lr,j}$ is the long-wave radiosity of surface j, in W/m²;

ρ is the long-wave radiative reflectance;

ε is the long-wave radiative emittance;

σ is the Stefan-Boltzmann constant: 5,670 × 10⁻⁸ W/(m²·K⁴).

In order to calculate the long-wave radiant heat flow exchanged by the N different inside surfaces, the radiosity, J_{lr}, for each surface shall be first determined by solving the N simultaneous formulae. The solution of Formula (30) shall be carried out for the various surfaces bounding the building zone.

Formula (30) may be solved by any appropriate procedure which provides results in accordance with the validation procedure given in Clause 8.

NOTE A suitable procedure is described in ISO/TR 52016-2[3].

6.4.5.5.3 Long-wave radiative heat transfer through air layers

The density of long-wave radiative heat transfer through air layers is given by Formula (31):

$$q_{lr} = \Lambda_{lr} \cdot \Delta\theta \tag{31}$$

where

q_{lr} is the density of the net long-wave radiant heat flow rate through the air layer, in W/m²;

$\Delta\theta$ is the temperature difference between the surfaces delimiting the air layer, in K;

Λ_{lr} is the long-wave radiative conductance of the air, in W/(m²·K).

6.4.5.6 Heat flow rate due to internal sources

Internal gains usually derive from lighting, equipment and occupants. The relevant heat flow rate consists of a convective component, $\Phi_{int,c}$, and a long-wave radiative component, $\Phi_{int,r}$, which are respectively included in Formulae (3) and (4). The long-wave radiative component, $\Phi_{int,r}$, is supposed to be uniformly distributed on all the internal surfaces bounding the zone, including windows.

6.4.5.7 Sensible space heating or cooling loads

The heat flow rate due to sensible space heating and/or cooling loads consists of a convective component, $\Phi_{HC;ld;c}$, and a long-wave radiative component, $\Phi_{HC;ld;r}$, which are respectively included in Formulae (3) and (4). The long-wave radiative component, $\Phi_{HC;ld;r}$, is supposed to be uniformly distributed on all the internal surfaces bounding the zone, including windows.

NOTE The sensible space heating or cooling load depends on the type and size of the heating or cooling system(s) and on the temperature controls. Details are to be given in the standards describing a specific application of the underlying calculation procedures, such as ISO 52016-1.

6.4.5.8 Heat flow rate due to ventilation

The net sensible heat flow rate to the zone air due to natural and mechanical ventilation shall be calculated according to Formula (32):

$$\Phi_V = c_a \cdot \rho_a \cdot q_{V;in} \cdot \left(\theta_{sup;a} - \theta_{int;a}\right) \tag{32}$$

where

Φ_V is the net heat flow rate to the zone air due to natural and mechanical ventilation, in W;

c_a is the specific heat capacity of the supply air, in J/(kg·K);

ρ_a is the density of dry air, in kg/m³;

$q_{V;in}$ is the total volume air flow rate entering the building zone, in m^3/s;

$\theta_{sup;a}$ is the supply air temperature, in °C;

$\theta_{int;a}$ is the internal air temperature, in °C.

NOTE The volume air flow rate and density of dry air are both a function of temperature and air pressure. The assumptions should be consistent, to ensure that the mass air flow rate remains the same under temperature and pressure variations. For instance, by assuming a reference temperature of 20 °C and pressure at sea level.

The supply air temperature depends on its source (e.g. external air or adjacent zone or, e.g. air handling or heat recovery unit). The air flow rate results from infiltration, natural and/or forced ventilation.

The latent heat flow due to ventilation shall be calculated according to Formula (33):

$$\Phi_{V;lat} = h_{we} \cdot \rho_a \cdot q_{V;in} \cdot \left(x_{sup;a} - x_{int;a} \right) \quad (33)$$

where

h_{we} is the latent heat of vaporization of water, in J/kg; h_{we} = 2 466 × 10^3 J/kg;

m_a is the total mass air flow rate, in kg/s;

$x_{sup;a}$ is the supply moisture content, in kg/kg(dry air);

$x_{int;a}$ is the internal moisture content, in kg/kg(dry air).

For the calculation, it is assumed that the air temperature is uniform throughout the building zone (see 6.4.2).

6.4.6 Building zone moisture and latent heat balance

6.4.6.1 Latent heat balance equation

The calculation considers the influx and outflux of moisture due to internal moisture production and ventilation and absorption or desorption of moisture in walls and other internal items, such as furniture and books.

However, in this document, there are no formulae or normative references given for such absorption/desorption. This calculation can be somewhat more complex than that of considering only temperature because heat and moisture in walls and others interact with each other.

NOTE 1 References, for instance on the calculation considering moisture absorption into or desorption from walls and others, are provided in the Bibliography of ISO/TR 52016-2[3].

With these assumptions, the mass flow rate for humidification and dehumidification or the humidity content of the internal air in a building or building zone, at any given time, is obtained by solving Formula (34):

$$\rho_{int;a}\, q_{V;in} \cdot \left(x_{sup;a} - x_{int;a} \right) + G_{int;a} - G_{abs;a} + G_{(D)HU;ld} = \rho_{int;a} \cdot V_{int;a} \cdot \frac{dx_{int;a}}{dt} \quad (34)$$

where

$\rho_{int;a}$ is the density of the internal dry air, in kg/m^3;

$q_{V;in}$ is the total volume air flow rate entering the building zone, in kg/s;

$x_{sup;a}$ is the supply air moisture content, in kg$_{H2O}$/kg(dry air);

$x_{int;a}$ is the humidity ratio or humidity content by mass of the internal air, in kg$_{H2O}$/kg(dry air);

$G_{int;a}$ is the moisture production in the zone, in kg$_{H2O}$/s;

$G_{abs;a}$ is the moisture absorption (positive value) or desorption (negative value) in materials in the zone, in kg$_{H2O}$/s;

$G_{(D)HU;ld}$ is the humidification moisture (supply) load (if positive), or dehumidification moisture (removal) load (if negative), in kg$_{H2O}$/s;

$\rho_{int;a}$ is the density of the indoor dry air, in kg/m^3;

$V_{int;a}$ is the volume of the indoor air, in m^3;

t is the time, in s.

NOTE 2 A specific application, with the necessary specific input data, assumptions and boundary conditions is given in ISO 52016-1.

6.4.6.2 Latent humidification and dehumidification loads

The heat flow rate for humidification and dehumidification, $\Phi_{HU;ld}$ or latent energy load expresses the latent energy needed to reach a specific moisture content of the considered thermal zone, within the given time interval. It is equal to the humidification and dehumidification moisture load, $G_{(D)HU;ld}$, multiplied by the latent heat of evaporation, h_{we}.

In that case, the humidification and dehumidification moisture load, $G_{(D)HU;ld}$, is the specific moisture mass flow that needs to be supplied to or extracted from the considered thermal zone, within the given time interval, to maintain a specified minimum or maximum humidity within the space.

The latent energy load depends on the humidity set point. The value is zero if there is no humidification or dehumidification. The latent energy need can be met by a local system or a central system; in the latter case, the value of the latent energy need may be set to zero and the need is satisfied by the moisture transferred by the ventilation air supplied to the considered thermal zone. Standards describing a specific application of the underlying calculation procedures may provide details.

6.4.7 Calculation steps

6.4.7.1 General

The calculation procedure involves the two consecutive steps:

a) specification of the starting conditions;

b) calculation of the internal conditions.

6.4.7.2 Specification of the starting conditions

The actual calculation period shall be preceded by an initialization period that is long enough to make the influence of the temperatures of each node at the start of the calculation negligible when the actual calculation period starts. The initialization period shall consist of the following:

— in case of a calculation of (a part of) an annual cycle: the period preceding the actual period (December preceding January);