INTERNATIONAL STANDARD

ISO 13791

Second edition
2012-03-15

Thermal performance of buildings — Calculation of internal temperatures of a room in summer without mechanical cooling — General criteria and validation procedures

Performance thermique des bâtiments — Calcul des températures intérieures en été d'un local sans dispositif de refroidissement — Critères généraux et procédures de validation

Reference number
ISO 13791:2012(E)

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 13791 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*.

This second edition cancels and replaces the first edition (ISO 13791:2004), which has been technically revised. The main changes compared to the previous edition are given in the following table:

Clause/subclause	Changes
2	Added ISO 9050, ISO 10292, ISO 15099, ISO 15927-2 and EN 673
3.2	Deleted q_a and v_m and added m_a
4.2.1	Amended Equation (1) Deleted $m_\mathrm{a,i}$ and added the descriptions of ρ_a and v_ai
4.5.6.1	Replaced q_a by m_a
8.3.9.1	Amended the values in Tables 22 and 23
8.3.9.2	Amended the values in Tables 24 and 25
I.2.2	Replaced m by m_a Amended Equation (I.1) and added the descriptions of n and Δp_0 Amended Equation (I.4) and added the description of ΔC_w Amended the unit used in Table I.1
I.2.3	Replaced m, m_w and m_T by m_a, $m_\mathrm{a,w}$ and $m_\mathrm{a,T}$, respectively Amended Equations (I.5), (I.6), (I.9), (I.10), (I.11), (I.12), (I.13) and (I.14) Replaced A by A_T in Equation (I.13) Replaced Δc_p by ΔC_w Added the descriptions of Equations (I.8) and (I.10)
I.2.3.3.3	Amended the description I.2.3.3.3
I.3.2	Replaced Δc_p by ΔC_w Replaced m_w by $m_\mathrm{a,w}$
I.3.3	Replaced m_T by $m_\mathrm{a,T}$
Annex J	Amended the values in Tables J.1 and J.2
Annex K	Added as a new annex

Introduction

This International Standard is intended for use by specialists to develop and/or validate methods for the hourly calculation of the internal temperatures of a single room.

Examples of application of such methods include:

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.

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

Thermal performance of buildings — Calculation of internal temperatures of a room in summer without mechanical cooling — General criteria and validation procedures

1 Scope

This International Standard specifies the assumptions, boundary conditions, equations and validation tests for a calculation procedure, under transient hourly conditions, of the internal temperatures (air and operative) during warm periods, of a single room without any cooling/heating equipment in operation. No specific numerical techniques are imposed by this International Standard. Validation tests are included in Clause 8. An example of a solution technique is given in Annex A.

This International Standard does not contain sufficient information for defining a procedure able to determine the internal conditions of special zones such as attached sun spaces, atria, indirect passive solar components (trombe walls, solar panels) and zones in which the solar radiation may pass through the room. For such situations different assumptions and more detailed solution models are needed (see Bibliography).

2 Normative references

The following referenced documents are indispensable for the application 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 9050, *Glass in building — Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors*

ISO 9251, *Thermal insulation — Heat transfer conditions and properties of materials — Vocabulary*

ISO 9288, *Thermal insulation — Heat transfer by radiation — Physical quantities and definitions*

ISO 9346, *Hygrothermal performance of buildings and building materials — Physical quantities for mass transfer — Vocabulary*

ISO 10077-1, *Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 1: General*

ISO 10077-2, *Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 2: Numerical method for frames*

ISO 10292, *Glass in building — Calculation of steady-state U values (thermal transmittance) of multiple glazing*

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

ISO 15099, *Thermal performance of windows, doors and shading devices — Detailed calculations*

ISO 15927-2, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 2: Hourly data for design cooling load*

EN 410, *Glass in building — Determination of luminous and solar characteristics of glazing*

EN 673, *Glass in building — Determination of thermal transmittance (U value) — Calculation method*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 9251, ISO 9288, ISO 9346 and the following apply.

3.1.1
internal environment
closed space delimited from the external environment or adjacent spaces by the building fabric

3.1.2
room element
wall, roof, ceiling, floor, door or window that separates the internal environment from the external environment or an adjacent space

3.1.3
room air
air of the internal environment

3.1.4
internal air temperature
temperature of the room air

3.1.5
internal surface temperature
temperature of the internal surface of a building element

3.1.6
mean radiant temperature
uniform surface temperature of an enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure

3.1.7
operative temperature
uniform temperature of an enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment

3.2 Symbols and units

For the purposes of this document, the following symbols and units apply.

Symbol	Definition	Unit
A	area	m^2
A_c	area of the surface in contact with the air layer	m^2
A_f	floor area	m^2
A_j	area of room element j	m^2
A_p	projected area of the considered system	m^2
A_s	sunlit area	m^2
A_{sh}	shaded area	m^2
a	thermal diffusivity	m^2/s
C	heat capacity	J/K
c	specific heat capacity	J/(kg·K)
c_a	specific heat capacity of air	J/(kg·K)
c_d	coefficient of discharge	—
c_{me}	specific heat capacity of the medium	J/(kg·K)
c_v	velocity coefficient	—
d	thickness	m
E_r	ventilation parameter	—
F	view factor	—
F_{sk}	view factor from the element with the sky	—
f_d	solar distribution factor	—
f_{ic}	internal convective factor	—
f_s	sunlit factor	—
f_{sa}	solar to air factor	—
f_{sl}	solar loss factor	—
G_i	moisture production	kg/s
G_v	moisture influx by ventilation	kg/s
g_s	heat flow rate per volume	W/m^3
g	acceleration due to gravity	m/s^2
H	height of the element	m
h	surface coefficient of heat transfer	$W/(m^2·K)$
h_a	convective heat transfer coefficient for ventilated layers	$W/(m^2·K)$
h_c	convective heat transfer coefficient of the surface	$W/(m^2·K)$
h_g	convective heat transfer coefficient for closed spaces	$W/(m^2·K)$
h_{lr}	long-wave radiative heat transfer coefficient	$W/(m^2·K)$

I	intensity of solar radiation	W/m^2
I_d	diffuse component of the solar radiation reaching the surface	W/m^2
I_D	direct component of the solar radiation reaching the surface	W/m^2
$J_{lr,j}$	long-wave radiosity	W/m^2
k	crack coefficient	—
l	length	m
m_a	mass air flow rate	kg/s
$m_{a,m}$	mass forced air flow rate by mechanical ventilation	kg/s
$m_{a,n}$	mass air flow rate by natural ventilation	kg/s
$m_{a,T}$	mass flow rate due to temperature	kg/s
$m_{a,w}$	mass flow rate due to wind	kg/s
n	flow exponent	—
p	pressure	Pa
q	density of heat flow rate	W/m^2
q_c	density of heat flow rate by convection	W/m^2
q_{cd}	density of heat flow rate by conduction	W/m^2
$q_{c,i}$	density of heat flow rate by conduction at the internal surface	W/m^2
q_{lr}	density of heat flow rate due to long-wave radiation exchanged with other internal surfaces	W/m^2
q_{sk}	correction for the long-wave radiation exchanges from the wall to the sky	W/m^2
q_{sr}	density of heat flow rate due to the absorbed short-wave radiation	W/m^2
R	thermal resistance	m^2·K/W
T	thermodynamic temperature	K
T_e	temperature of the environment	K
T_{in}	temperature of the air entering the air layer	K
T_{out}	temperature of the air leaving the layer	K
t	time	s
U	thermal transmittance	W/(m^2·K)
V	volume	m^3
v	velocity	m/s
x,y,z	co-ordinates	m
Λ	thermal conductance	W/(m^2·K)
Φ	heat flow rate	W
Φ_i	heat flow rate due to internal sources	W
Φ_{sa}	solar to air heat flow rate	W
Φ_{sr}	heat flow rate of solar radiation entering the room	W

Φ_v	heat flow rate by ventilation	W
Φ_{va}	heat flow rate due to the air entering the room through air layers within the elements bounding the room	W
α	solar absorptance	—
ε	long-wave emissivity of the surface	
θ	celsius temperature	°C
$\theta_{a,d}$	defined air temperature of the adjacent room	°C
$\theta_{a,e}$	air temperature of the adjacent room	°C
$\theta_{a,i}$	temperature of the internal air	°C
θ_v	temperature of the mechanically supplied air	°C
λ	thermal conductivity	W/(m·K)
μ	viscosity	kg/(m·s)
ν_i	humidity by volume of internal air	kg/m^3
ν_{in}	humidity by volume of inflowing air	kg/m^3
ρ	solar reflectance	—
ρ_a	density of air	kg/m^3
ρ_m	average solar reflection coefficient of room surfaces	—
ρ_{me}	density of the medium	kg/m^3
$\rho_{a,o}$	density of the air at the temperature T_0	kg/m^3
σ	Stefan-Boltzmann constant	$W/(m^2 \cdot K^4)$

3.3 Subscripts

a	air	cd	conduction
b	building	ec	external ceiling
c	convection	ef	external floor
D	direct solar radiation	eq	equivalent
d	diffuse solar radiation	ic	internal ceiling
e	external	if	internal floor
g	ground	il	inlet section
i	internal	lr	long-wave radiation
l	leaving the section	mr	mean radiant
n	normal to surface	op	operative
r	radiation	sa	solar to air
s	surface	sk	sky
sl	solar loss	t	time
sr	short-wave radiation	v	ventilation
va	ventilation through air cavity		

4 Determination of internal temperatures

4.1 Assumptions

The evaluation of the internal temperature of a room involves the solution of a system of equations of the transient heat and mass transfers between the external and internal environment through the opaque and transparent elements bounding the room envelope. The procedures given in this International Standard allow the user to determine the time-dependent temperature of each component, including the internal air. Accepted assumptions for the calculation of the internal temperatures of a single room under transient conditions in absence of any cooling plant are:

— the air temperature is uniform throughout the room;

— the various surfaces of the room elements are isothermal;

— the thermophysical properties of the materials composing the room elements are time-independent;

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

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

— the effect of thermal bridges is generally neglected, but if it is considered the heat storage contribution of the thermal bridges is neglected;

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

— convective heat transfer coefficients: at the external surface they depend on the wind velocity and direction, at the internal surface they depend on the direction of the heat flow;

— the long-wave radiative heat flow rate at the external surfaces of the room elements is related to a time-independent heat transfer coefficient;

— the external radiant environment (sky excluded) is at the external air temperature (see 4.5.4.1);

— the distribution of solar radiation within the room is time-independent;

— the dimensions of each element are measured inside the room;

— the mean radiant temperature is calculated by weighting the various internal surface temperatures according to the relevant areas;

— the operative temperature is the average between the internal air temperature and the mean surface temperature.

4.2 Evaluation of the relevant temperatures

4.2.1 Internal air temperature

The air temperature of a room, at any given time, is obtained by solving Equation (1), where heat flow rates to room air are taken as positive:

$$\sum_{j=1}^{N}(A\, q_{\mathrm{c,i}})_j + \Phi_{\mathrm{v}} + \Phi_{\mathrm{i,c}} + \Phi_{\mathrm{sa}} + \Phi_{\mathrm{va}} = c_{\mathrm{a}}\, \rho_{\mathrm{a}} V_{\mathrm{a,i}} \frac{\partial \theta_{\mathrm{a,i}}}{\partial t} \tag{1}$$

where

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

A is the area of each building element;

$q_{c,i}$ is the density of the heat flow rate by convection at the internal surface (see 4.5.2.2);

Φ_v is the heat flow rate by ventilation (see 4.5.6);

$\Phi_{i,c}$ is the convective part of heat flow rate due to internal sources (see 4.5.5);

Φ_{sa} is the solar to air heat flow rate (see 4.5.3.4);

Φ_{va} is the heat flow rate due to the air entering the room through air layers within the elements bounding the room;

c_a is the specific heat capacity of air;

ρ_a is the density of the internal air;

$V_{a,i}$ is the volume of the internal air;

$\theta_{a,i}$ is the temperature of the internal air;

t is the time.

NOTE Because of the very small value of the term (ρ_a $V_{a,i}$) the right-hand side of Equation (1) can be assumed to be zero.

4.2.2 Internal surface temperature

The internal surface temperature at element j is obtained by solving Equation (2), where heat flow rates to the internal surface, except $q_{c,j}$, are taken as positive:

$$q_{lr,j} + q_{sr,j} + q_{c,j} + q_{cd,j} + \frac{\Phi_{i,r}}{\sum_{j=1}^{N} A_j} = 0 \qquad (2)$$

where

q_{lr} is the density of heat flow rate due to long-wave radiation exchanged with other internal surfaces (see 4.5.4.2);

q_{sr} is the density of heat flow rate due to the absorbed short-wave radiation (see 4.5.3.2);

q_c is the density of heat flow rate released to room air by convection (see 4.5.2.2);

q_{cd} is the density of heat flow rate by conduction (see 4.5.1);

$\Phi_{i,r}$ is the heat flow rate due to the radiative component of internal gains (see 4.5.5);

N is the number of surfaces delimiting the internal air;

A_j is the area of room element j.