SIST

SLOVENSKI STANDARD
SIST EN ISO 13791:2005

01-februar-2005

Toplotne znaļ ilnosti stavb - Izraļ un notranje temperature prostorov poleti brez mehanskega hlajenja - Sploġna merila in validacija postopka (ISO 13791:2004)

Thermal performance of buildings - Calculation of internal temperatures of a room in summer without mechanical cooling - General criteria and validation procedures (ISO 13791:2004)

Wärmetechnisches Verhalten von Gebäuden - Sommerliche Raumtemperaturen bei Gebäuden ohne Anlagentechnik - Allgemeine Kriterien und Validierungsverfahren (ISO 13791:2004)

Performance thermique des bâtiments - Température intérieure en été d'un local non climatisé - Criteres généraux et méthodes de calculs (ISO 13791:2004)

Ta slovenski standard je istoveten z: **EN ISO 13791:2004**

ICS:

91.120.10 Toplotna izolacija stavb Thermal insulation

SIST EN ISO 13791:2005 **en**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 13791

November 2004

ICS 91.120.10

English version

Thermal performance of buildings - Calculation of internal temperatures of a room in summer without mechanical cooling - General criteria and validation procedures (ISO 13791:2004)

Performance thermique des bâtiments - Calcul des températures intérieures en été d'un local sans dispositif de refroidissement - Critères généraux et méthodes de calcul (ISO 13791:2004)

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This European Standard was approved by CEN on 7 June 2004.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN ISO 13791:2004: E

Contents

Foreword

This document (EN ISO 13791:2004) has been prepared by Technical Committee CEN/TC 89 "Thermal performance of buildings and building components", the secretariat of which is held by SIS, in collaboration with Technical Committee ISO/TC 163, “Thermal performance and energy use in the built environment”, Subcommittee SC 2, "Calculation methods".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2005, and conflicting national standards shall be withdrawn at the latest by May 2005.

This standard is one of a series of standards on calculation methods for the design and the evaluation of the thermal performance of buildings and building components.

This document includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This document 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 standard can also be used as a reference to develop more simplified methods for the above and similar applications.

1 Scope

This document 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 the warm period, of a single room without any cooling/heating equipment in operation. No specific numerical techniques are imposed by this document. Validation tests are included in Clause 7. An example of a solution technique is given in Annex A.

This document 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.

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

EN ISO 6946, *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method (ISO 6946:1996).*

EN ISO 7345, *Thermal insulation – Physical quantities and definitions (ISO 7345:1987).*

EN ISO 9251, *Thermal insulation – Heat transfer conditions and properties of materials – Vocabulary (ISO 9251:1987).*

EN ISO 9288, *Thermal insulation – Heat transfer by radiation – Physical quantities and definitions (ISO 9288:1989).*

EN ISO 9346, *Thermal insulation – Mass transfer – Physical quantities and definitions (ISO 9346:1987).*

EN ISO 10077-1, *Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: Simplified method (ISO 10077-1:2000).*

EN ISO 10077-2, *Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames (ISO 10077-2:2003).*

EN ISO 13370, *Thermal performance of buildings – Heat transfer via the ground – Calculation methods (ISO 13370:1998).*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 7345, EN ISO 9251, EN ISO 9288 and EN 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 with which an occupant would exchange the same amount of radiant heat as with the actual non-uniform enclosure

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

3.2 Symbols and units

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

Symbol	Quantity	Unit
A	area	m^2
A_s	sunlit area	m^2
C	heat capacity	J/K
F	view factor	-
I	intensity of solar radiation	W/m^2
R	thermal resistance	$m^2 \cdot K/W$
T	thermodynamic temperature	K
U	thermal transmittance	$W/(m^2 \cdot K)$
V	volume	m^3
a	thermal diffusivity	m^2/s
c	specific heat capacity	J/(kg·K)
c_d	coefficient of discharge	-
c_p	specific heat capacity of air at constant pressure	J/(kg·K)
d	thickness	m
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	heat flow rate per volume	W/m^3
h	surface coefficient of heat transfer	$W/(m^2 \cdot K)$
l	length	m
m	mass	kg
q_a	mass air flow rate	kg/s
p	pressure	Pa
q	density of heat flow rate	W/m^2
t	time	s
v	velocity	m/s
x,y,z	co-ordinates	m
Λ	thermal conductance of air layer	$W/(m^2 \cdot K)$
Φ	heat flow rate	W
J	total radiosity	W/m^2
α	solar absorptance	-
ε	total hemispherical emissivity	-
θ	Celsius temperature	°C
λ	thermal conductivity	W/(m·K)
μ	dynamic viscosity	kg/(m·s)
ρ	solar reflectance	-

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
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 document 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 EN ISO 13370;

— the effect of thermal bridges are generally neglected, but if they are considered their heat storage contribution 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:

$$\sum_{j=1}^{N}(Aq_{c,i})_j + \Phi_v + \Phi_{i,c} + \Phi_{sa} + \Phi_{va} = c_a\, m_{a,i} \frac{\partial \theta_{a,i}}{\partial t} \qquad (1)$$

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 (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;

$m_{a,i}$ is the mass 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 ($c_a\, m_{a,i}$) 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:

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

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.

4.2.3 Surface delimiting two solid layers

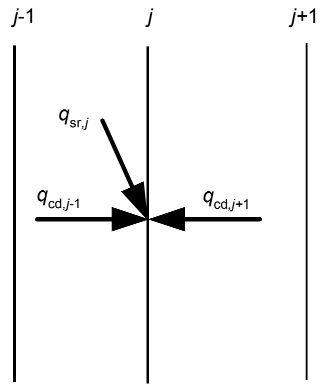


Figure 1 - Surface delimiting two layers

The temperature at surface j delimiting two layers in an element (Figure 1) is obtained by solving Equation (3):

$$q_{cd,j-1} + q_{cd,j+1} + q_{sr,j} = 0 \qquad (3)$$

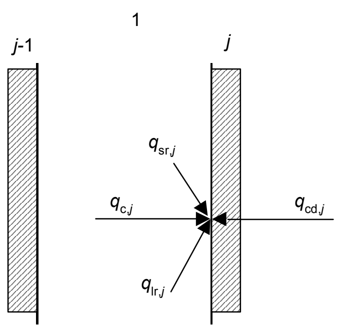
where

$q_{cd,j-1}$ is the density of heat flow rate by conduction from the j-1 surface (see 4.5.1);

$q_{cd,j+1}$ is the density of heat flow rate by conduction from the j+1 surface (see 4.5.1);

$q_{sr,j}$ is the density of heat flow rate due to the solar radiation absorbed by the surface j.

4.2.4 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 (Figure 2) is obtained by solving Equation (4):

$$q_{c,j} + q_{lr,j} + q_{cd,j} + q_{sr,j} = 0 \quad (4)$$

where

q_c is the density of the total heat flow rate released to the air layer (see 4.5.2);

q_{lr} is the density of the heat flow rate received by long-wave radiation across the air layer (see 4.5.4);

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

q_{sr} is the density of heat flow rate absorbed due to an external source (e.g. solar radiation).

4.2.5 External surface of a room element

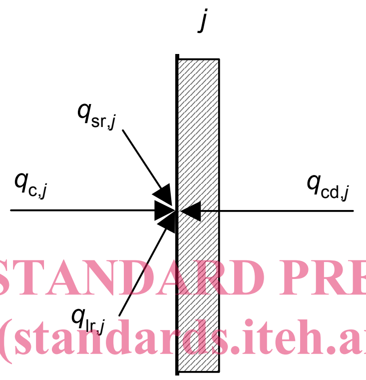


Figure 3 - External surface of an element

The temperature at surface *j* of a room element (Figure 3) is obtained by solving Equation (5):

$$q_{lr,j} + q_{sr,j} + q_{c,j} + q_{cd,j} = 0 \quad (5)$$

where

q_{lr} is the density of heat flow rate by long-wave radiation at the surface (see 4.5.4.1);

q_{sr} is the density of heat flow rate due to the short-wave radiation absorbed by the surface (see 4.5.3.1);

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

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

4.2.6 Relevant temperatures for special construction elements

4.2.6.1 Ceiling below an attic

The ceiling, the air space and the roof are considered as a single horizontal element with one-dimensional heat flow. The air space is considered as an air layer, treated in 4.5.2.3 and 4.5.2.4.

4.2.6.2 Floor on ground

The floor and the soil are considered as a single horizontal element with the heat flow treated according to EN ISO 13370. Boundary conditions are specified in 4.4.4.

4.2.6.3 Floor over cellar

The cellar is treated as an unheated basement according to EN ISO 13370. Boundary conditions are specified in 4.4.3.

4.2.6.4 Floor over crawl space

The floor, the crawl space and the soil are treated as a suspended floor according to EN ISO 13370. Boundary conditions are specified in 4.4.5.

4.2.6.5 Glazed element

A glazed element is composed of a number of planes (glazing panes and possibly blinds) which are in thermal equilibrium with one another. The evaluation of temperatures of each plane is made using the following assumptions:

— the heat storage effects in the various planes are neglected;

— the heat flow by convection through the air layers between each pane is calculated according to 4.5.2.3 and 4.5.2.4;

— the density of heat flow rate due to the long-wave radiation between the various planes is calculated according to 4.5.4.3;

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

4.3 Room thermal balance

In each equation of 4.2, 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 step considered. A general expression of the equation system is:

$$\begin{pmatrix} \Pi_{1,1} & \Pi_{1,2} & \Pi_{1,N} & \Pi_{1,N+1} \\ \Pi_{2,1} & \Pi_{2,2} & \Pi_{2,N} & \Pi_{2,N+1} \\ \Pi_{N,1} & \Pi_{N,2} & \Pi_{N,N} & \Pi_{N,N+1} \\ \Pi_{N+1,1} & \Pi_{N+1,2} & \Pi_{N+1,N} & \Pi_{N+1,N+1} \end{pmatrix} \cdot \begin{pmatrix} \theta_{\text{is},1} \\ \theta_{\text{is},2} \\ \theta_{\text{is},N} \\ \theta_{\text{a}} \end{pmatrix} = \begin{pmatrix} \Gamma_1 \\ \Gamma_2 \\ \Gamma_N \\ \Gamma_{N+1} \end{pmatrix} \tag{6}$$

where

N is the number of elements bounding the room 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 Equation (1) and Equation (2) in order to separate the unknown parameters (air temperature at the given time t for Equation (1) and the internal surface temperature for each component at the given time t for Equation (2)) from the known parameters. The form of these equations depends on the solution technique adopted.