SLOVENSKI STANDARD

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Grelni sistemi v stavbah - Naļrtovanje vodnih sistemov za ogrevanje in hlajenje, vgrajenih v gradbeno konstrukcijo - 3. del: Optimizacija rabe obnovljivih energijskih virov

Heating systems in buildings - Design of embedded water based surface heating and cooling systems - Part 3: Optimizing for use of renewable energy sources

Heizungssysteme in Gebäuden - Planung von eingebetteten Flächenheiz- und kühlsystemen mit Wasser als Arbeitsmedium - Teil 3: Optimierung für die Nutzung erneuerbarer Energiequellen

Conception des systemes de chauffage et refroidissement par le sol, le mur et le plafond - Partie 3 : Optimisation pour l'usage des sources d'énergie renouvelable

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91.140.10	Sistemi centralnega ogrevanja	Central heating systems

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Heating systems in buildings - Design of embedded water based surface heating and cooling systems - Part 3: Optimizing for use of renewable energy sources

Conception des systèmes de chauffage et refroidissement par le sol, le mur et le plafond - Partie 3 : Optimisation pour l'usage des sources d'énergie renouvelable

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This European Standard was approved by CEN on 18 August 2007.

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Foreword

This document (EN 15377-3:2007) has been prepared by Technical Committee CEN/TC 228 “Heating systems in buildings”, the secretariat of which is held by DS.

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of an identical text or by endorsement, at the latest by April 2008, and conflicting national standards shall be withdrawn at the latest by April 2008.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/343), and supports essential requirements of EU Directive 2002/91/EC on the energy performance of buildings (EPBD). It forms part of a series of standards aimed at European harmonisation of the methodology for calculation of the energy performance of buildings. An overview of the whole set of standards is given in prCEN/TR 15615.

The subjects covered by CEN/TC 228 are the following:

- design of heating systems (water based, electrical etc.);
- installation of heating systems;
- commissioning of heating systems;
- instructions for operation, maintenance and use of heating systems;
- methods for calculation of the design heat loss and heat loads;
- methods for calculation of the energy performance of heating systems.

Heating systems also include the effect of attached systems such as hot water production systems.

All these standards are systems standards, i.e. they are based on requirements addressed to the system as a whole and not dealing with requirements to the products within the system.

Where possible, reference is made to other European or International Standards, a.o. product standards. However, use of products complying with relevant product standards is no guarantee of compliance with the system requirements.

The requirements are mainly expressed as functional requirements, i.e. requirements dealing with the function of the system and not specifying shape, material, dimensions or the like.

The guidelines describe ways to meet the requirements, but other ways to fulfil the functional requirements might be used if fulfilment can be proved.

Heating systems differ among the member countries due to climate, traditions and national regulations. In some cases requirements are given as classes so national or individual needs may be accommodated.

In cases where the standards contradict with national regulations, the latter should be followed.

prEN 15377 *Heating systems in buildings – Design of embedded water based surface heating and cooling systems* consists of the following parts:

Part 1: Determination of the design heating and cooling capacity

Part 2: Design, dimensioning and installation

Part 3: Optimizing for use of renewable energy sources

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

Introduction

The aim of the present standard is to give a guide for the design of water based embedded heating and cooling systems to promote the use of renewable energy sources and to provide a method for actively integrating the building mass to reduce peak loads, transfer heating/cooling loads to off-peak time periods and to decrease systems size.

A section in the present standard describes how the design and dimensioning can be improved to facilitate renewable energy sources.

Peak loads can be reduced by activating the building mass using pipes embedded in the main concrete structure of the building (**T**hermo-**A**ctive-**B**uilding-**S**ystems, TABS). For this type of systems, the steady state calculation of heating and cooling capacity (part 1 of this standard) is not sufficient. Thus, several sections of this standard describe methods for taken into account the dynamic behavior.

The proposed methods are used to calculate and verify that the cooling capacity of the system is sufficient and to calculate the cooling requirements on the water side for sizing the cooling system.

The energetic assessment of surface heating and cooling systems may also be carried out according to national guidelines accomplishing the goal of this standard.

1 Scope

This document is applicable to water based surface heating and cooling systems in residential, commercial and industrial buildings.

The methods apply to systems integrated into the wall, floor or ceiling construction without any open air gaps.

The methods do not apply to heated or chilled ceiling panels or beams.

This standard is part 3 of a series of standards:

— *Part 1: Determination of the design heating and cooling capacity*;

— *Part 2: Design, dimensioning and installation*;

— *Part 3:Optimizing for use of renewable energy sources*.

The aim of the present standard is to give a guide for the design to promote the use of renewable energy sources and to provide a method for the use of Thermo-Active-Building-Systems (TABS).

The method allows calculation of peak cooling capacity of a thermo-active system, based on heat gains (solar, internal loads, ventilation).

This method also allows calculation of the energy demand on the water side (system) to be used for sizing of the cooling system, e.g. chiller, fluid flow rate.

Steady state heating capacity is calculated according to method B or E of prEN 15377-1 (part 1 of this series of standards).

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15251, *Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*

EN 15255, *Thermal performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures*

EN 15265, *Energy performance of buildings - Calculation of energy needs for space heating and cooling using dynamic methods - General criteria and validation procedures*

prEN 15377-1:2005, *Heating systems in buildings – Design of embedded water based surface heating and cooling systems — Part 1: Determination of the design heating and cooling capacity*

prEN 15377-2, *Heating systems in buildings — Design of embedded water based surface heating and cooling systems — Part 2: Design, dimensioning and installation*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in prEN 15377-1:2005 and the following symbols apply.

3.1 Data referred to the circuit:

$\dot{m}_{H,sp}$ specific water flow, calculated on the area covered by the circuit kg/ (m^2 s) ;

c_w specific heat capacity of the water J/ (kg K) ;

T pipe spacing m ;

d_a external diameter of the pipe m ;

s_r thickness of the pipe wall m ;

λ_r thermal conductivity of the material of the pipe wall W/ (m K) ;

A_{Floor} area cooled/heated by the circuit m^2 ;

L_R length of the circuit m ;

P_W^{Max} maximum cooling (<0) or heating (>0) power for a conditioning plant W ;

θ_w^0 supply water temperature at the beginning of the simulation °C ;

$\theta_w^{\lim}$ minimum (in the cooling case) or maximum (in the heating case) supply water temperature obtainable by the machine °C .

3.2 Data referred to the room geometry and the boundary conditions:

A_{Walls} overall area of vertical walls, external facade excluded m^2 ;

$F_{v\ Floor\text{-}Ext\ Wall}$ view factor floor-external wall;

$F_{v\ Floor\text{-}Ceiling}$ view factor floor-ceiling;

$F_{v\ Floor\text{-}Walls}$ view factor floor-walls;

$R_{add\ Floor}$ additional resistance covering the upper side of the slab (m^2 K)/W ;

$R_{add\ Ceiling}$ additional resistance covering the lower side of the slab (m^2 K)/W ;

R_{Walls} resistance of the surface layer of internal walls (m^2 K)/W ;

$h_{Air\text{-}Floor}$ convective heat transfer coefficient between the air and the floor W/(m^2 K) ;

$h_{Air\text{-}Ceiling}$ convective heat transfer coefficient between the air and the ceiling W/(m^2 K) ;

$h_{Air\text{-}Walls}$ convective heat transfer coefficient between the air and the internal walls W/(m^2 K) ;

$h_{Floor\text{-}Walls}$ radiant heat transfer coefficient between the floor and the internal walls W/(m^2 K) ;

$h_{Floor\text{-}Ceiling}$ radiant heat transfer coefficient between the floor and the ceiling W/(m^2 K) ;

$h_{Ceiling\text{-}Walls}$ radiant heat transfer coefficient between the ceiling and the internal walls W/(m^2 K) ;

C_{Walls} average specific thermal inertia of the internal walls J/(m^2 K)

Δt calculation time step s .

The following data shall be known for all the day, and the values during the n-th time step from the beginning of the simulation have to be defined:

$T_{comfort}$ maximum operative temperature allowed for comfort conditions °C ;

$\dot{Q}_{Sun}^{n}$ solar gain in the room in the present calculation time step W ;

$\dot{Q}_{Transm}^{n}$ incoming heat flux to the room from the external wall in the present calculation time step W ;

$\dot{Q}_{Air}^{n}$ convective heat flux extracted by the air circuit W ;

$\dot{Q}_{IntRad}^{n}$ internal radiant heat gain due to people or electrical equipment in the present calculation time step W ;

$\dot{Q}_{IntConv}^{n}$ internal convective heat gain due to people or electrical equipment in the present calculation time step W ;

f_{rm}^{n} running mode (the value is 1 when the system is running and 0 when the system is switched off) dimensionless ;

3.3 Data referred to the slab and its partitions:

s_1 thickness of the upper part of the slab m ;

s_2 thickness of the lower part of the slab m ;

J_1 number of material layers constituting the upper part of the slab dimensionless ;

J_2 number of material layers constituting the lower part of the slab dimensionless ;

As a consequence, $J=J_1+J_2$ represents the total number of material layers constituting the slab and J sets of physical properties (ρ_j, c_j, λ_j, δ_j, m_j, R_j) shall be known or chosen, where:

ρ_j density of the material constituting the j-th layer kg/m³ ;

c_j specific heat capacity of the material constituting the j-th layer J/ (kg K) ;

λ_j thermal conductivity of the j-th layer W/ (m K) ;

δ_j thickness of the j-th layer m ,
$\delta_j = 0$ if the layer is a mere thermal resistance;

m_j number of partitions of the j-th layer dimensionless ;

R_j thermal resistance summarizing the j-th layer m²K/W ,
$R_j > 0$ if the layer is a mere thermal resistance.

For geometrical consistency: $\sum_{j=1}^{J_1} \delta_j = s_1 \quad and \quad \sum_{j=J_1}^{J_1+J_2} \delta_j = s_2$.

3.4 Data referred to the initial temperature profile

The initial value of the supply water temperature (θ_w^0) and the interface temperatures of partitions of the slab ($\theta_{\mathrm{I},i}^0$ with $0 \le i \le i_L$) shall be decided. As for the slab, a possible choice could be assigning the same value to all the interfaces, equal to the mean temperature at the start of the simulation.

However, if the simulation covers more than one running cycle, the choice of the initial values is not decisive. In fact, it will influence only the very first time steps of the simulation.

3.5 Calculation of the temperature profile and the heat fluxes in the generic time-step n

The temperature reached at a certain interface at the end of the previous time step is used for calculation of the heat fluxes acting on the building structures and for calculation of the consequent temperatures at the end of the time step in progress. These magnitudes are:

$\dot{q}^n_{Conv}$ global specific convective heat gains W/m^2 ;

$\dot{q}^n_{Rad}$ global specific radiant heat gains W/m^2 ;

θ^n_{Air} air temperature in the room in the present calculation time step °C ;

θ^n_{Walls} mean temperature of the walls in the present calculation time step °C ;

θ^n_{Op} operative temperature in the room in the present calculation time step °C ;

θ^{n-1}_{w} supply water temperature at the end of the previous time step °C ;

$\theta^{n-1}_{w\ exit}$ outlet water temperature at the end of the previous time step °C ;

$\theta^{n-1}_{I,i}$ temperature of the i-th interface, with $0 \le i \le i_L$, at the end of the previous time step, °C ;

The results obtained at every time step are:

θ^n_{w} supply water temperature at the end of the time step in progress °C ;

θ^n_{F} , θ^n_{s} temperature of the upper and lower sides of the slab at the end of the time step in progress °C ;

$\theta^n_{I,i}$ temperature of the i-th interface, with $0 \le i \le i_L$, at the end of the time step in progress, °C .

4 Relation to other EPBD standards

The present standard requires input from the following standards: prEN 15377-1, EN 15251, EN 15255 and EN 15265.

The present standard provides input data to the following standards: EN 15243 and EN ISO 13792.

5 Optimisation of systems for facilitating the use of renewable energy sources

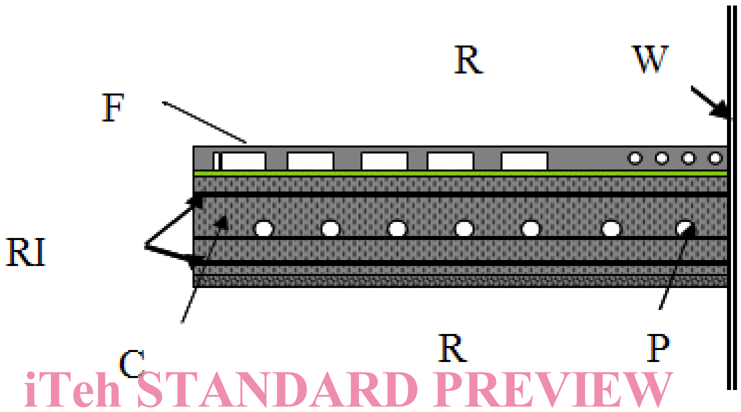
Transporting energy by water uses less auxiliary energy for pumps and less installation space than carrying the same amount of energy by air. A further optimizing is to use water at temperatures close to room temperature for heating and cooling: low temperature heating - high temperature cooling.

For normal embedded radiant floor-, wall-, and ceiling heating/cooling systems, increasing the pipe spacing and decreasing the difference between supply and return water temperature results in water temperatures closer to room temperature, but this increases flow rates and pipe lengths leading to higher pressure losses. This forces designers to choose between either increasing auxiliary energy use for pumps or applying pipes with a larger diameter, both of which are undesirable options. This can partly be compensated by using more circuits of shorter pipe lengths. These factors shall be optimized according to prEN 15377-2 (part 2 of this series of standards).

For Thermo-Active-Building–Systems, a further optimization regarding use of renewable energy sources is made by reducing the peak load, transferring the load to off-peak time periods, downsizing of energy generation systems, and increased efficiency of energy generation due to water temperature level. This facilitates the possible use of energy sources such as solar collectors, ground source heat pumps, free cooling, ground source heat exchangers, aquifers.

6 The concept of Thermo-Active-Building-Systems (TABS)

A Thermo-Active-Building-System (TABS) is a water based heating and cooling system, where the pipes are embedded in the central concrete core of a building construction (see Figure 1). The heat transfer takes place between the water (pipes) and the concrete, between the concrete core and the surfaces to the room (ceiling, floor) and between the surfaces and the room.

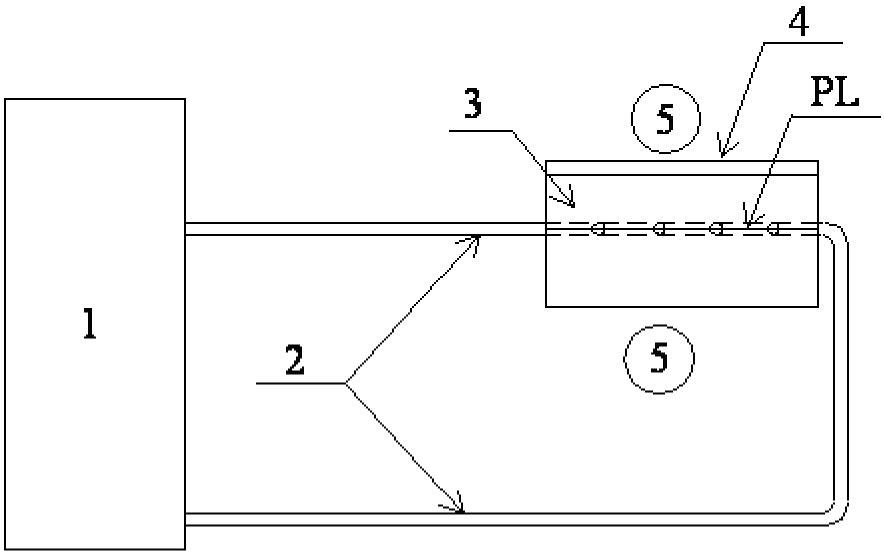


Key

W	window	P	pipes
R	room	C	concrete
F	floor	RI	reinforcement

Figure 1 – Thermo-active radiant system

Looking at a typical structure of a thermo-active system, heat is removed by a cooling system (e.g. chiller, heat pump) connected to pipes embedded in the slab. The system can be divided into the following elements (see Figure 2):



where:

PL = pipes level

1 = cooling system (machine)

2 = hydraulic circuit

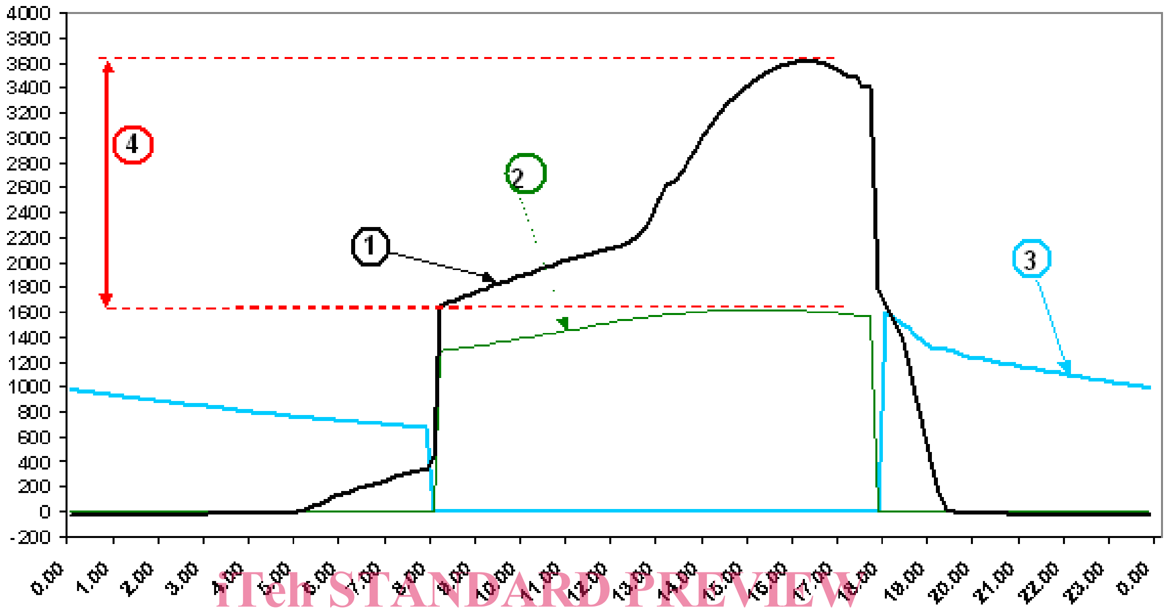
3 = slab including core level with pipes

4 = possible additional resistances (floor covering or suspended ceiling)

5 = room below and room above

Figure 2 – Simple scheme of a thermo-active system

Peak-shaving is the possibility to heat and cool the structures of the building during a period in which the occupants may be absent (e.g. during night time), reducing also the peak of the required power (see Figure 3). In this way, energy consumption may be reduced and a lower night time electricity rate (if obtainable) can be exploited, and furthermore, downsizing of the cooling system, including the chiller, is possible.



Key

1	heat gain	X-axis	time of the day
2	power needed for conditioning the ventilation air	Y-axis	cooling power
3	power needed on the water side		
4	peak of the required power reduction		

Figure 3 – Example of peak-shaving effect

TABS may be used both with natural and mechanical ventilation (depending on weather conditions). Mechanical ventilation with dehumidifying may be required depending on external climate and indoor humidity production. In the example in Figure 3, the required cooling power needed for dehumidifying the air during day time is sufficient for cooling the slab during night time.

The designer needs to know if the capacity at a given water temperature is sufficient to keep the room temperature in a given range. The designer needs also to know the heat flow on the water side to be able to dimension the heat distribution system and the chiller/boiler. The present document provides methods for this.

Some detailed building-systems calculation models have been developed, e.g. for determination of the heat exchanges under non-steady state conditions in a single room, for determination of thermal and hygrometric balance of the room air, for prediction of comfort conditions, for checking of condensation on surfaces, for availability of control strategies and for calculation of the incoming solar radiation. The use of such detailed calculation models is, however, limited due to the high amount of time needed for the simulations. Development of a more user-friendly tool is required. Such a tool is provided in the following, which allows simulation of thermo-active systems in an easy way.

Internal temperature changes only moderately during the day, and the aim of a good design of TABS is to maintain comfort during the day within the range of comfort, i.e. –0,5 < PMV < 0,5, according to EN 15251 (see Figure 4).