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Building environment design — Design, dimensioning, installation and control of embedded radiant heating and cooling systems —

Part 2: Determination of the design heating and cooling capacity

Conception de l'environnement des bâtiments — Conception, construction et fonctionnement des systèmes de chauffage et de refroidissement par rayonnement —

Partie 2: Détermination de la puissance calorifique et frigorifique à la conception

Reference number
ISO 11855-2:2012(E)

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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.

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 11855-2 was prepared by Technical Committee ISO/TC 205, *Building environment design*.

ISO 11855 consists of the following parts, under the general title *Building environment design — Design, dimensioning, installation and control of embedded radiant heating and cooling systems*:

— *Part 1: Definition, symbols, and comfort criteria*

— *Part 2: Determination of the design and heating and cooling capacity*

— *Part 3: Design and dimensioning*

— *Part 4: Dimensioning and calculation of the dynamic heating and cooling capacity of Thermo Active Building Systems (TABS)*

— *Part 5: Installation*

— *Part 6: Control*

Part 1 specifies the comfort criteria which should be considered in designing embedded radiant heating and cooling systems, since the main objective of the radiant heating and cooling system is to satisfy thermal comfort of the occupants. Part 2 provides steady-state calculation methods for determination of the heating and cooling capacity. Part 3 specifies design and dimensioning methods of radiant heating and cooling systems to ensure the heating and cooling capacity. Part 4 provides a dimensioning and calculation method to design Thermo Active Building Systems (TABS) for energy-saving purposes, since radiant heating and cooling systems can reduce energy consumption and heat source size by using renewable energy. Part 5 addresses the installation process for the system to operate as intended. Part 6 shows a proper control method of the radiant heating and cooling systems to ensure the maximum performance which was intended in the design stage when the system is actually being operated in a building.

Introduction

The radiant heating and cooling system consists of heat emitting/absorbing, heat supply, distribution, and control systems. The ISO 11855 series deals with the embedded surface heating and cooling system that directly controls heat exchange within the space. It does not include the system equipment itself, such as heat source, distribution system and controller.

The ISO 11855 series addresses an embedded system that is integrated with the building structure. Therefore, the panel system with open air gap, which is not integrated with the building structure, is not covered by this series.

The ISO 11855 series shall be applied to systems using not only water but also other fluids or electricity as a heating or cooling medium.

The object of the ISO 11855 series is to provide criteria to effectively design embedded systems. To do this, it presents comfort criteria for the space served by embedded systems, heat output calculation, dimensioning, dynamic analysis, installation, operation, and control method of embedded systems.

Building environment design — Design, dimensioning, installation and control of embedded radiant heating and cooling systems —

Part 2: Determination of the design heating and cooling capacity

1 Scope

This part of ISO 11855 specifies procedures and conditions to enable the heat flow in water based surface heating and cooling systems to be determined relative to the medium differential temperature for systems. The determination of thermal performance of water based surface heating and cooling systems and their conformity to this part of ISO 11855 is carried out by calculation in accordance with design documents and a model. This should enable a uniform assessment and calculation of water based surface heating and cooling systems.

The surface temperature and the temperature uniformity of the heated/cooled surface, nominal heat flow density between water and space, the associated nominal medium differential temperature, and the field of characteristic curves for the relationship between heat flow density and the determining variables are given as the result.

This part of ISO 11855 includes a general method based on Finite Difference or Finite Element Methods and simplified calculation methods depending on position of pipes and type of building structure.

The ISO 11855 series is applicable to water based embedded 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. It does not apply to panel systems with open air gaps which are not integrated into the building structure.

The ISO 11855 series also applies, as appropriate, to the use of fluids other than water as a heating or cooling medium. The ISO 11855 series is not applicable for testing of systems. The methods do not apply to heated or chilled ceiling panels or beams.

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 11855-1:2012, *Building environment design — Design, dimensioning, installation and control of embedded radiant heating and cooling systems — Part 1: Definition, symbols, and comfort criteria*

EN 1264-2, *Water based surface embedded heating and cooling systems — Part 2: Floor heating: Prove methods for the determination of the thermal output using calculation and test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11855-1:2012 apply.

4 Symbols and abbreviations

For the purposes of this document, the symbols and abbreviations in Table 1 apply.

Table 1 — Symbols and abbreviations

Symbol	Unit	Quantity
α_i	—	Parameter factors for calculation of characteristic curves
A_A	m^2	Surface of the occupied area
A_F	m^2	Surface of the heating/cooling surface area
A_R	m^2	Surface of the peripheral area
b_u	—	Calculation factor depending on the pipe spacing
B, B_G, B_0	$W/(m^2 \cdot K)$	Coefficients depending on the system
D	m	External diameter of the pipe, including sheathing where used
d_a	m	External diameter of the pipe
d_i	m	Internal diameter of the pipe
d_M	m	External diameter of sheathing
c_W	$kJ/(kg \cdot K)$	Specific heat capacity of water
h_t	$W/(m^2 \cdot K)$	Total heat exchange coefficient (convection + radiation) between surface and space
K_H	$W/(m^2 \cdot K)$	Equivalent heat transmission coefficient
K_{WL}	—	Parameter for heat conducting devices
k_{fin}	—	Parameter for heat conducting devices
k_{CL}	—	Parameter for heat conducting layer
L_{WL}	m	Width of heat conducting devices
L_{fin}	m	Width of fin (horizontal part of heat conducting device seen as a heating fin)
L_R	m	Length of installed pipes
m	—	Exponents for determination of characteristic curves
m_H	kg/s	Design heating/cooling medium flow rate
n, n_G	—	Exponents
q	W/m^2	Heat flux at the surface
q_A	W/m^2	Heat flux in the occupied area
q_{des}	W/m^2	Design heat flux
q_G	W/m^2	Limit heat flux
q_N	W/m^2	Nominal heat flux
q_R	W/m^2	Heat flux in the peripheral area
q_u	W/m^2	Outward heat flux
R_o	$m^2 \cdot K/W$	Partial inwards heat transmission resistance of surface structure
R_u	$m^2 \cdot K/W$	Partial outwards heat transmission resistance of surface structure
$R_{\lambda,B}$	$m^2 \cdot K/W$	Thermal resistance of surface covering

$R_{\lambda,ins}$	$m^2 \cdot K/W$	Thermal resistance of thermal insulation
s_h	m	In Type B systems, thickness of thermal insulation from the outward edge of the insulation to the inward edge of the pipes (see Figure 2)
s_l	m	In Type B systems, thickness of thermal insulation from the outward edge of the insulation to the outward edge of the pipes (see Figure 2)
s_{ins}	m	Thickness of thermal insulation
s_R	m	Pipe wall thickness
s_u	m	Thickness of the layer above the pipe
s_{WL}	m	Thickness of heat conducting device
S	m	Thickness of the screed (excluding the pipes in type A systems)
W	m	Pipe spacing
α	$W/(m^2 \cdot K)$	Heat exchange coefficient
$\theta_{s,max}$	°C	Maximum surface temperature
$\theta_{s,min}$	°C	Minimum surface temperature
θ_i	°C	Design indoor temperature
θ_m	°C	Temperature of the heating/cooling medium
θ_R	°C	Return temperature of heating/cooling medium
θ_V	°C	Supply temperature of heating/cooling medium
θ_u	°C	Indoor temperature in an adjacent space
$\Delta\theta_H$	K	Heating/cooling medium differential temperature
$\Delta\theta_{H,des}$	K	Design heating/cooling medium differential temperature
$\Delta\theta_{H,G}$	K	Limit of heating/cooling medium differential temperature
$\Delta\theta_N$	K	Nominal heating/cooling medium differential temperature
$\Delta\theta_V$	K	Heating/cooling medium differential supply temperature
$\Delta\theta_{V,des}$	K	Design heating/cooling medium differential supply temperature
λ	$W/(m \cdot K)$	Thermal conductivity
σ	K	Temperature drop $\theta_V - \theta_R$
φ	—	Conversion factor for temperatures
ψ	—	Content by volume of the attachment burrs in the screed

5 Concept of the method to determine the heating and cooling capacity

A given type of surface (floor, wall, ceiling) delivers, at a given average surface temperature and indoor temperature (operative temperature θ_i), the same heat flux in any space independent of the type of embedded system. It is therefore possible to establish a basic formula or characteristic curve for cooling and a basic formula or characteristic curve for heating, for each of the type of surfaces (floor, wall, ceiling), independent of the type of embedded system, which is applicable to all heating and cooling surfaces (see Clause 6).

Two methods are included in this part of ISO 11855:

— simplified calculation methods depending on the type of system (see Clause 7);

— Finite Element Method and Finite Difference Method (see Clause 8).

Different simplified calculation methods are included in Clause 7 for calculation of the surface temperature (average, maximum and minimum temperature) depending on the system construction (type of pipe, pipe diameter, pipe distance, mounting of pipe, heat conducting devices, distribution layer) and construction of the floor/wall/ceiling (covering, insulation layer, trapped air layer, etc.). The simplified calculation methods are specific for the given type of system, and the boundary conditions listed in Clause 7 shall be met. In the calculation report, it shall be clearly stated which calculation method has been applied.

In case a simplified calculation method is not available for a given type of system, either a basic calculation using two or three dimensional finite element or finite difference method can be applied (see Clause 8 and Annex D).

NOTE In addition, laboratory testing (for example EN 1264-2:2008, Clause 9) may be applied.

Based on the calculated average surface temperature at given combinations of medium (water) temperature and space temperature, it is possible to determine the steady state heating and cooling capacity (see Clause 9).

6 Heat exchange coefficient between surface and space

The relationship between the heat flux and mean differential surface temperature [see Figure 1 and Equations (1) to (4)] depends on the type of surface (floor, wall, ceiling) and whether the temperature of the surface is lower (cooling) or higher (heating) than the space temperature.

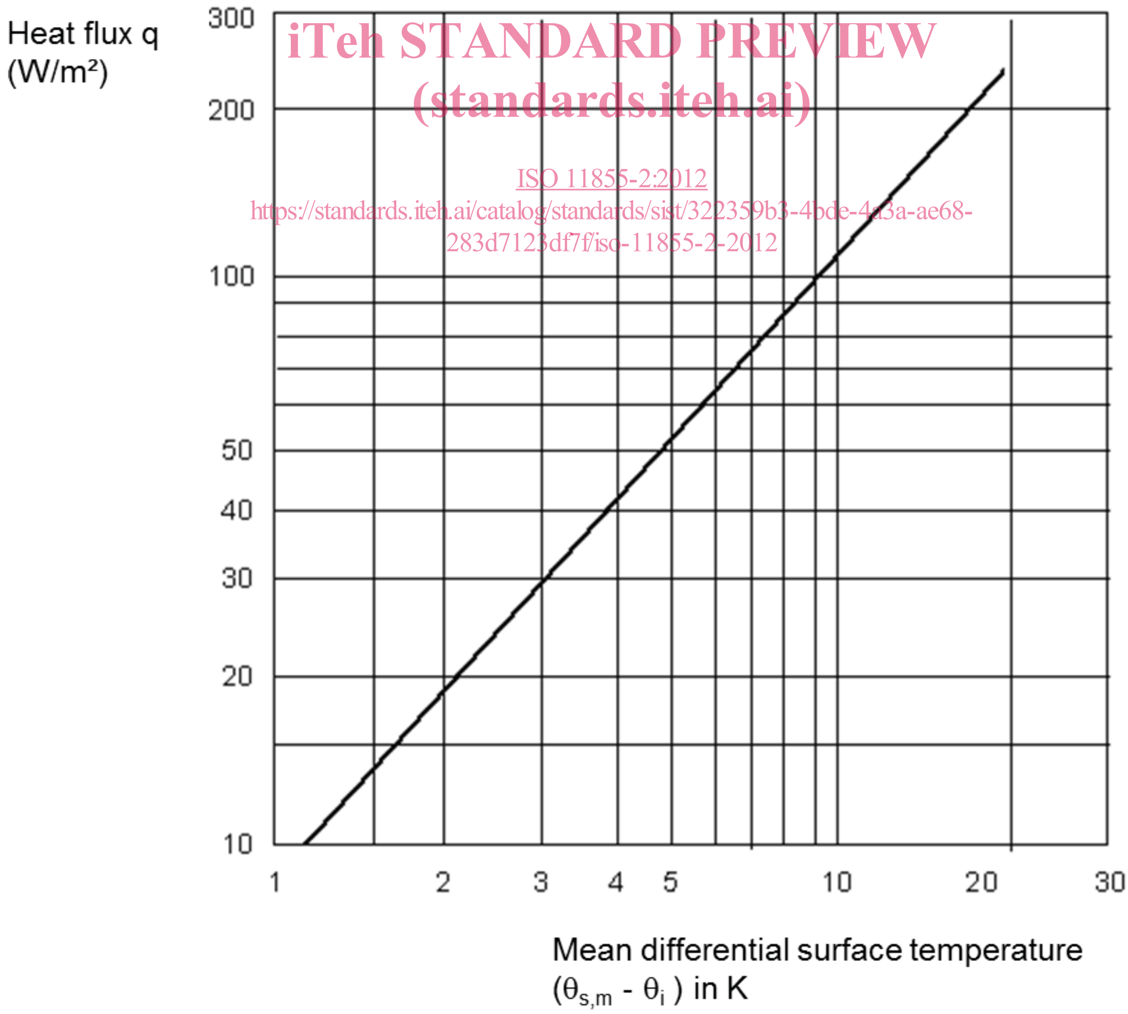


Figure 1 — Basic characteristic curve for floor heating and ceiling cooling

For floor heating and ceiling cooling in Figure 1, the heat flow density q is given by:

$$q = 8{,}92\ (\theta_{S,m} - \theta_i)^{1,1}\ (\text{W/m}^2) \qquad (1)$$

where

$\theta_{S,m}$ is the average surface temperature in°C;

θ_i is the nominal indoor operative temperature in °C.

For other types of surface heating and cooling systems, the heat flux q is given by:

Wall heating and wall cooling: $q = 8\ (|\theta_{s,m} - \theta_i\ |)\ (\text{W/m}^2)$ (2)

Ceiling heating: $q = 6\ (|\theta_{s,m} - \theta_i\ |)\ (\text{W/m}^2)$ (3)

Floor cooling: $q = 7\ (|\theta_{s,m} - \theta_i\ |)\ (\text{W/m}^2)$ (4)

The heat transfer coefficient is combined convection and radiation.

NOTE In many building system simulations using dynamic computer models, the heat transfer is often split up in a convective part (between heated/cooled surface and space air) and a radiant part (between heated/cooled surface and the surrounding surfaces or sources). The radiant heat transfer coefficient may in the normal temperature range 15-30 °C be fixed to 5,5 W/m²K. The convective heat transfer coefficient depends on type of surface, heating or cooling, air velocity (forced convection) or temperature difference between surface and air (natural convection).

For using the simplified calculation method in Annex A the characteristic curves present the heat flux as a function of the difference between the heating/cooling medium temperature and the indoor temperature. For the user of Annex A, this means not to do any calculations by directly using values of heat exchange coefficients. Consequently, Annex A does not include values for such an application or special details or equations concerning heat exchange coefficients on heating or cooling surfaces.

Thus, the values α of Table A.12 of Annex A are not intended to calculate the heat flux directly. In fact, they are provided exclusively for the conversion of characteristic curves in accordance with Equation (A.32) in Clause A.3. For simplifications these calculations are based on the same heat exchange coefficient for floor cooling and ceiling heating, 6,5 W/m²K.

For every surface heating and cooling system, there is a maximum allowable heat flux, the limit heat flux q_G. This is determined for a selected design indoor room temperature of θ_i (for heating, often 20 °C and for cooling, often 26 °C) at the maximum or minimum surface temperature $\theta_{F,max}$ and a temperature drop $\sigma = 0$ K.

For the calculations, the centre of the heating or cooling surface area, regardless of the type of system, is used as a reference point for $\theta_{S,max}$.

The average surface temperature, $\theta_{S,m}$, which determines the heat flow density (refer to the basic characteristic curve) is linked with the maximum or minimum surface temperature: $\theta_{S,m} < \theta_{S,max}$ and. $\theta_{S,m} > \theta_{S,min}$ always applies.

The attainable value, $\theta_{S,m}$, depends not only on the type of system, but also on the operating conditions (temperature drop $\sigma = \theta_V - \theta_R$, outward heat flow q_u and heat resistance of the covering $R_{\lambda,B}$).

The following assumptions form the basis for calculation of the heat flux:

— heat transfer between the heated or cooled surface and the space occurs in accordance with the basic characteristic curve;

— the temperature drop $\sigma = 0$. The dependence of the characteristic curve on the temperature drop is determined by using the logarithmically determined mean differential heating medium temperature $\Delta\theta_H$ [see Equation (1)];

— turbulent flow in pipe: $\frac{m_H}{d_i} > 4000 \frac{kg}{h \cdot m}$;

— no lateral heat flow.

7 Simplified calculation methods for determining heating and cooling capacity or surface temperature

Two types of simplified calculation methods can be applied according to this part of ISO 11855:

— one method is based on a single power function product of all relevant parameters developed from the finite element method (FEM);

— another method is based on calculation of equivalent thermal resistance between the temperature of the heating or cooling medium and the surface temperature (or room temperature).

A given system construction can only be calculated with one of the simplified methods. The correct method to apply depends on the type of system, A to G (position of pipes, concrete or wooden construction) and the boundary conditions listed in Table 2.

Table 2 — Criteria for selection of simplified calculation method

Pipe position	Type of system	Figure	Boundary conditions	Reference to method
In screed Thermally decoupled from the structural base of the building by thermal insulation	A, C	2 a)	$W \geq 0{,}050$ m $s_u \geq 0{,}01$ m $0{,}008$ m $\leq d \leq 0{,}03$ m $s_u/\lambda_e \geq 0{,}01$	7.1 A.2.2
In insulation, conductive devices Not wooden constructions except for weight bearing and thermal diffusion layer	B	2 b)	$0{,}05$ m $\leq W \leq 0{,}45$ m $0{,}014$ m $\leq d \leq 0{,}022$ m $0{,}01$ m $\leq s_u/\lambda_e \leq 0{,}18$	7.1 A.2.3
Plane section system	D	2 c)		7.1, A.2.4
In concrete slab	E	4	$S_T / W \geq 0{,}3$	7.2, B.1
Capillar tubes in concrete surface	F	5	$d_a/W \leq 0{,}2$	7.2, B.2
Wooden constructions, pipes in sub floor or under sub floor, conductive devices	G	6	$\lambda_{wl} \geq 10\ \lambda_{surroundingmaterial}$ $S_{WL}\ \lambda \geq 0{,}01$	7.2, Annex C

7.1 Universal single power function

The heat flux between embedded pipes (temperature of heating or cooling medium) and the space is calculated by the general equation:

$$q = B \cdot \prod_i (a_i^{m_i}) \cdot \Delta\theta_H \ \ (\mathrm{W/m^2}) \qquad (5)$$

where

B	is a system-dependent coefficient in $\mathrm{W/(m^2 \cdot K)}$. This depends on the type of system;
$\prod_i (a_i^{m_i})$	is the power product, which links the parameters of the structure (surface covering, pipe spacing, pipe diameter and pipe covering).

This calculation method is given in Annex A for the following four types of systems:

— Type A with pipes embedded in the screed or concrete (see Figure 2 and A.2.2);

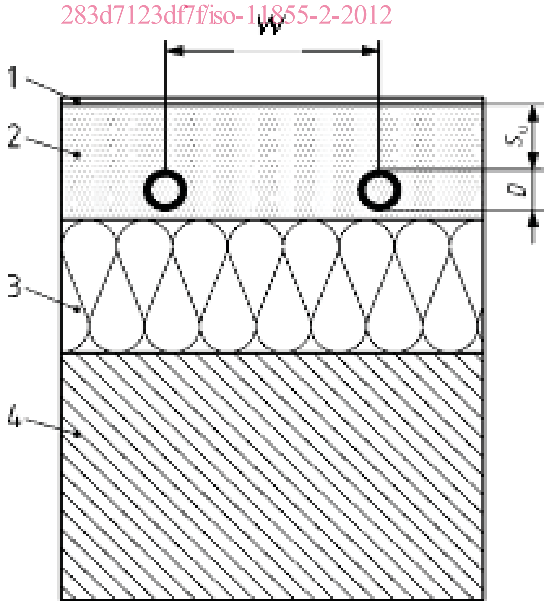
— Type B with pipes embedded outside the screed (see Figure 2 and A.2.3);

— Type C with pipes embedded in the screed (see Figure 2 and A.2.2);

— Type D plane section systems (see A.2.4).

Figure 2 shows the types as embedded in the floor, but the methods can also be applied for wall and ceiling systems with a corresponding position of the pipes.

This method shall only be used for system configurations meeting the boundary conditions listed for the different types of systems in Annex A.



a) Type A and C

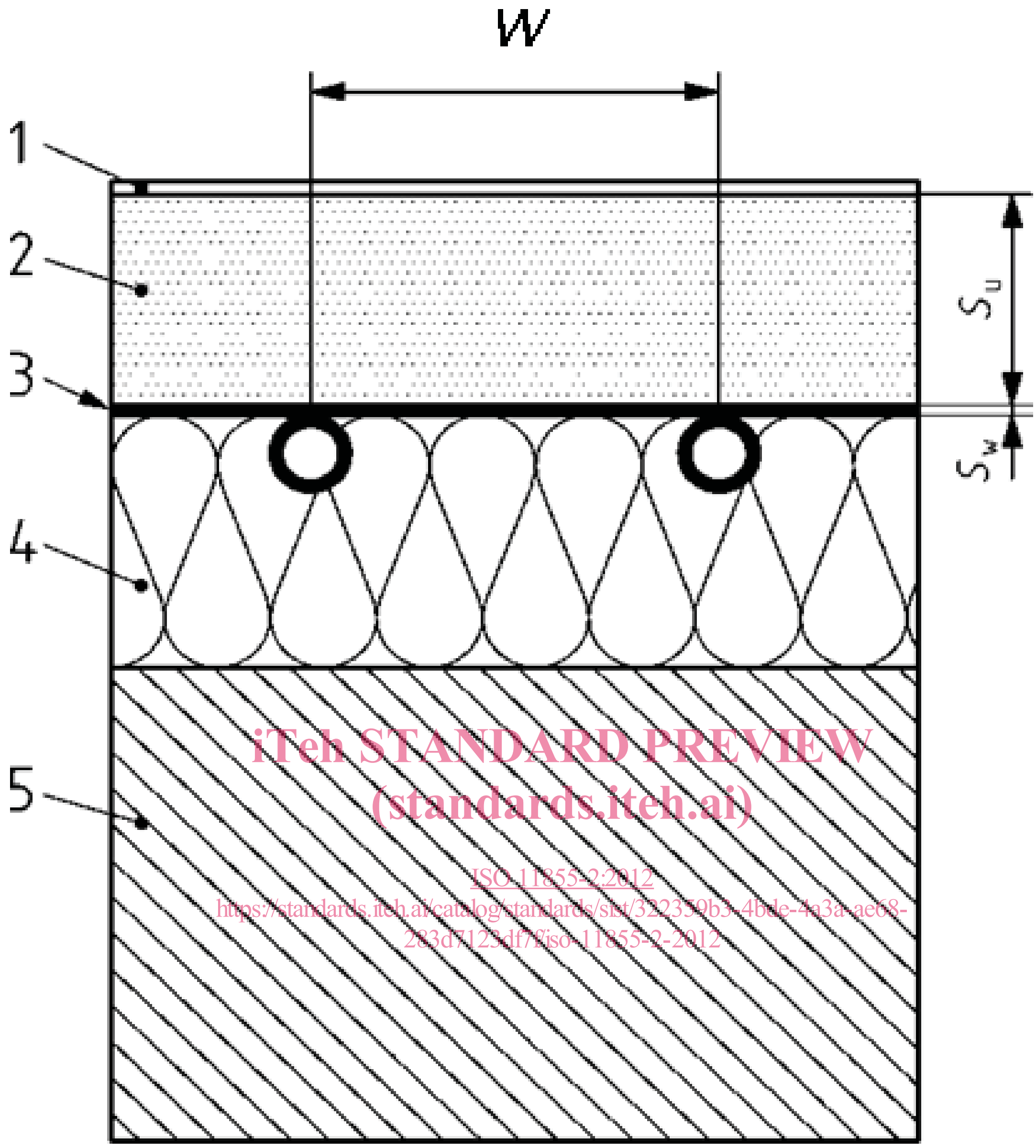
Key

1 floor covering

2 weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed)

3 thermal insulation

4 structural bearing



b) Type B

Key

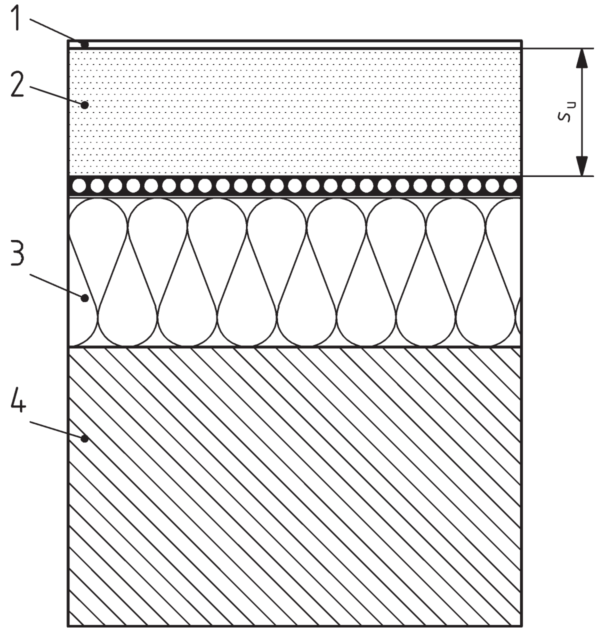
1 floor covering

2 weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed, wood)

3 heat diffusion devices

4 thermal insulation

5 structural bearing



c) Type D

Key

1 floor covering R_λ, B

2 weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed, timber)

3 thermal insulation

4 structural bearing

Figure 2 — System types A, B and C covered by the method in Annex A

7.2 Thermal resistance methods

The heat flux between embedded pipes (temperature of heating or cooling medium) and the space or surface is calculated using thermal resistances.

The concept is shown in Figure 3.

An equivalent resistance, R_{HC}, between the heating or cooling medium to a fictive core (or heat conduction layer) at the position of the pipes is determined. This resistance includes the influence of type of pipe, pipe distance and method of pipe installation (in concrete, wooden construction, etc.). In this way a fictive core temperature is calculated. The heat transfer between this fictive layer and the surfaces, R_i and R_e (or space and neighbour space) is calculated using linear resistances (adding of resistance of the layers above and below the heat conductive layer).

The equivalent resistance of the heat conductive layer is calculated in different ways depending on the type of system.

This calculation method, using the general resistance concept, is given in Annex B for the following two types of systems:

— Type E with pipes embedded in massive concrete slabs (see Figure 4 and B.1);

— Type F with capillary pipes embedded in a layer at the inside surface (see Figure 5 and B.2).

