

FINAL
DRAFT

INTERNATIONAL
STANDARD

ISO/FDIS
11855-2

ISO/TC 205

Secretariat: ANSI

Voting begins on:
2021-06-14

Voting terminates on:
2021-08-09

Building environment design — Embedded radiant heating and cooling systems —

Part 2: Determination of the design heating and cooling capacity

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*Conception de l'environnement des bâtiments — Systèmes intégrés de
chauffage et de refroidissement par rayonnement —*

*Partie 2: Détermination de la puissance calorifique et frigorifique à la
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Reference number
ISO/FDIS 11855-2:2021(E)

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Published in Switzerland

Contents

	Page
Foreword.....	iv
Introduction.....	v
1 Scope.....	1
2 Normative references.....	1
3 Terms and definitions.....	1
4 Symbols.....	1
5 Concept of the method to determine the heating and cooling capacity.....	3
6 Heat exchange coefficient between surface and space.....	4
7 Simplified calculation methods for determining heating and cooling capacity or surface temperature.....	6
7.1 Universal single power function.....	7
7.2 Thermal resistance methods.....	9
8 Use of basic calculation programmes.....	12
8.1 Basic calculation programmes.....	12
8.2 Items to be included in a complete computation documentation.....	13
9 Calculation of the heating and cooling capacity.....	13
Annex A (normative) Calculation of the heat flux.....	14
Annex B (informative) General resistance method.....	36
Annex C (informative) Pipes embedded in wooden construction.....	42
Annex D (normative) Method for verification of FEM and FDM calculation programmes.....	50
Annex E (normative) Values for heat conductivity of materials and air layers.....	53
Annex F (informative) Maximal surface temperatures for floor heating systems.....	55
Bibliography.....	56

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).

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

For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 205, *Building environment design*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 228, *Heating systems and water based cooling systems in buildings*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 11855-2:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

- update of the figures for type A and C,
- update of the thermal, relevant material characteristics,
- editorial corrections.

A list of all parts in the ISO 11855 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 is applicable to water-based embedded surface heating and cooling systems in buildings. The ISO 11855 series is applied to systems using not only water but also other fluids or electricity 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.

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, control method of embedded systems, and input parameters for the energy calculations.

The ISO 11855 series consists of the following parts, under the general title Building environment design — Embedded radiant heating and cooling systems:

- Part 1: Definitions, symbols, and comfort criteria
- Part 2: Determination of the design 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 7: Input parameters for the energy calculation

ISO 11855-1 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. ISO 11855-2, this document, provides steady-state calculation methods for determination of the heating and cooling capacity. ISO 11855-3 specifies design and dimensioning methods of radiant heating and cooling systems to ensure the heating and cooling capacity. ISO 11855-4 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. ISO 11855-5 addresses the installation process for the system to operate as intended. ISO 11855-6 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. ISO 11855-7 presents a calculation method for input parameters to ISO 52031.

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Building environment design — Embedded radiant heating and cooling systems —

Part 2:

Determination of the design heating and cooling capacity

1 Scope

This document specifies procedures and conditions to enable the heat flux 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 document is carried out by calculation in accordance with design documents and a model. This enables 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 flux between water and space, the associated nominal medium differential temperature, and the field of characteristic curves for the relationship between heat flux and the determining variables are given as the result.

This document 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.

2 Normative references

ISO/FDIS 11855-2

<https://www.iso.org/standards/catalog/standards/sist/2c90e18-7794-46f2-bc23-44767b71566e/iso-fdis-11855-2>

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 11855-1, *Building environment design — Embedded radiant heating and cooling systems — Part 1: Definitions, symbols, and comfort criteria*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Symbols

For the purposes of this document, the symbols in [Table 1](#) apply.

Table 1 — Symbols

Symbol	Unit	Quantity
A_A	m ²	Surface of the occupied area
A_F	m ²	Surface of the heating or cooling surface area

Table 1 (continued)

Symbol	Unit	Quantity
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_{Wa}	$kJ/(kg \cdot K)$	Specific heat capacity of water
h_t	$W/(m^2 \cdot K)$	Total heat transfer coefficient (convection + radiation) between surface and space
h_{A-F}	$W/(m^2 \cdot K)$	Total heat transfer coefficient (convection + radiation) between surface and space (floor)
h_{A-W}	$W/(m^2 \cdot K)$	Total heat transfer coefficient (convection + radiation) between surface and space (wall)
h_{A-C}	$W/(m^2 \cdot K)$	Total heat transfer coefficient (convection + radiation) between surface and space (ceiling)
K_H	$W/(m^2 \cdot K)$	Equivalent heat transmission coefficient
K_{WL}	—	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_D	—	Exponents for determination of characteristic curves
m_u	—	Exponents for determination of characteristic curves
m_T	—	Exponents for determination of characteristic curves
m_H	kg/s	Design heating or 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

Table 1 (continued)

Symbol	Unit	Quantity
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
h	W/(m ² ·K)	Heat exchange coefficient
α_i	—	Parameter factors for calculation of characteristic curves
λ_{WL}	W/(m·K)	Heat conductivity of the heat diffusion device material
$\theta_{s,max}$	°C	Maximum surface temperature
$\theta_{s,min}$	°C	Minimum surface temperature
θ_i	°C	Design indoor temperature
θ_m	°C	Temperature of the heating or cooling medium
$\theta_{s,m}$	°C	Average surface temperature
θ_R	°C	Return temperature of heating or cooling medium
θ_V	°C	Supply temperature of heating or cooling medium
θ_u	°C	Indoor temperature in an adjacent space
$\Delta\theta_H$	K	Heating or cooling medium differential temperature
$\Delta\theta_{H,des}$	K	Design heating or cooling medium differential temperature
$\Delta\theta_{H,G}$	K	Limit of heating or cooling medium differential temperature
$\Delta\theta_N$	K	Nominal heating or cooling medium differential temperature
$\Delta\theta_V$	K	Heating or cooling medium differential supply temperature
$\Delta\theta_{V,des}$	K	Design heating or cooling medium differential supply temperature
λ	W/(m·K)	Thermal conductivity
σ	K	Temperature drop $\theta_V - \theta_R$
φ	—	Conversion factor for temperatures
ψ	—	Volume ratio of the attachment studs 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 document:

- 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 ([Annex E](#)), 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.

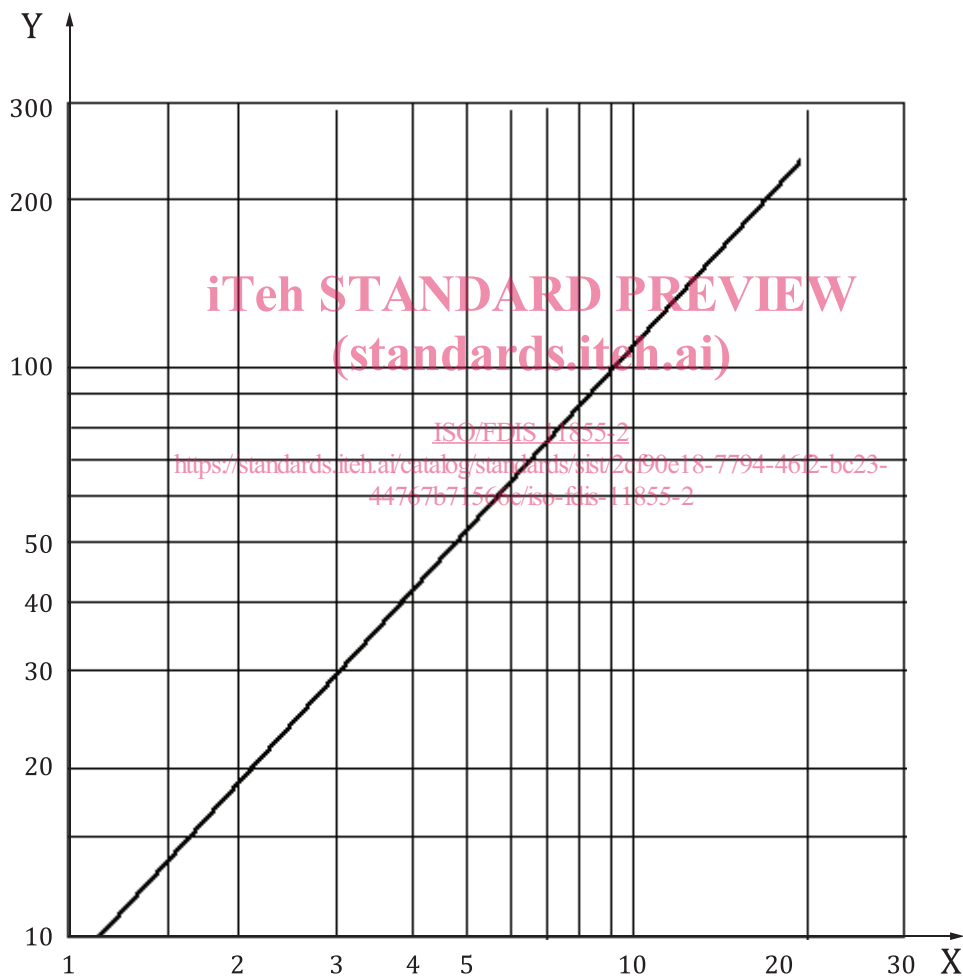
In case a simplified calculation method is not available for a given type of system, either a basic calculation using two or three dimensional finite element or finite difference method can be applied (see [Clause 8](#) and [Annex D](#)).

NOTE In addition, laboratory testing (for example, EN 1264) can 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 [Formulae \(1\) 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.



Key

- X mean differential surface temperature $(\theta_{s,m} - \theta_i)$ in K
- Y heat flux q (W/m^2)

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

For floor heating and ceiling cooling in [Figure 1](#), the heat flux q is given by:

$$q = 8,92 (\theta_{S,m} - \theta_i)^{1,1} \quad (1)$$

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:

$$q = 8 (|\theta_{S,m} - \theta_i|) \quad (2)$$

Ceiling heating:

$$q = 6 (|\theta_{S,m} - \theta_i|) \quad (3)$$

Floor cooling:

$$q = 7 (|\theta_{S,m} - \theta_i|) \quad (4)$$

NOTE 1 Heat flux, q , is expressed in W/m^2 .

The heat transfer coefficient is combined convection and radiation.

NOTE 2 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 in the normal temperature range (15-30) °C can be fixed to 5,5 $W/m^2 \cdot K$. 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).

By using the simplified calculation method in [Annex A](#), the characteristic curves present the heat flux as a function of the difference between the heating or 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 transfer coefficients. Consequently, [Annex A](#) does not include values for such an application or special details or formulae concerning heat transfer coefficients on heating or cooling surfaces.

Thus, the values α of [Table A.20](#) are not intended to calculate the heat flux directly. In fact, they are provided exclusively for the conversion of characteristic curves in accordance with [Formula \(A.33\)](#). For simplifications these calculations are based on the same heat transfer coefficient for floor cooling and ceiling heating, 6,5 $W/(m^2 \cdot K)$.

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 flux (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. (See [Annex F](#) for the maximal surface temperature for floor heating systems.)

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 flux q_u and heat resistance of the covering $R_{\lambda,B}$).

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

- the heat transfer between the heated or cooled surface and the space occurs in accordance with the basic characteristic curve;
- the temperature drop is $\sigma = 0$ K. 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 [Formula \(1\)](#)];
- the turbulent pipe flow is: $\frac{m_H}{d_i} > 4\,000 \frac{\text{kg}}{\text{h}\cdot\text{m}}$;
- there is no lateral heat flux;
- the heat-conducting layer of the floor heating system is thermally decoupled by thermal insulation from the structural base of the building. The thermal insulation does not need to be directly below the system.

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 document:

- 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](#).

NOTE Type A is a system with pipes embedded in the thermal diffusion layer . Type C is a system with pipes embedded in the adjustment layer.

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, H, I, J	2 a)	$W \geq 0,050 \text{ m}$ $s_u \geq 0,01 \text{ m}$ $0,008 \text{ m} \leq d \leq 0,03 \text{ m}$ $s_u/\lambda_e \geq 0,01$	7.1 A.2.2
In insulation, conductive devices Not wooden constructions except for weight bearing and thermal diffusion layer	B	2 b)	$0,05 \text{ m} \leq W \leq 0,45 \text{ m}$ $0,014 \text{ m} \leq d \leq 0,022 \text{ m}$ $0,01 \text{ m} \leq s_u/\lambda_e \leq 0,18 \text{ m}$	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
Capillary 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	$\lambda_{wl} \geq 10 \lambda$ $S_{WL\lambda} \geq 0,01$	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 [Formula \(5\)](#):

$$q = B \cdot \prod_i (a_i^{m_i}) \cdot \Delta\theta_H \quad (5)$$

where

B is a system-dependent coefficient in $W/(m^2 \cdot K)$, 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).

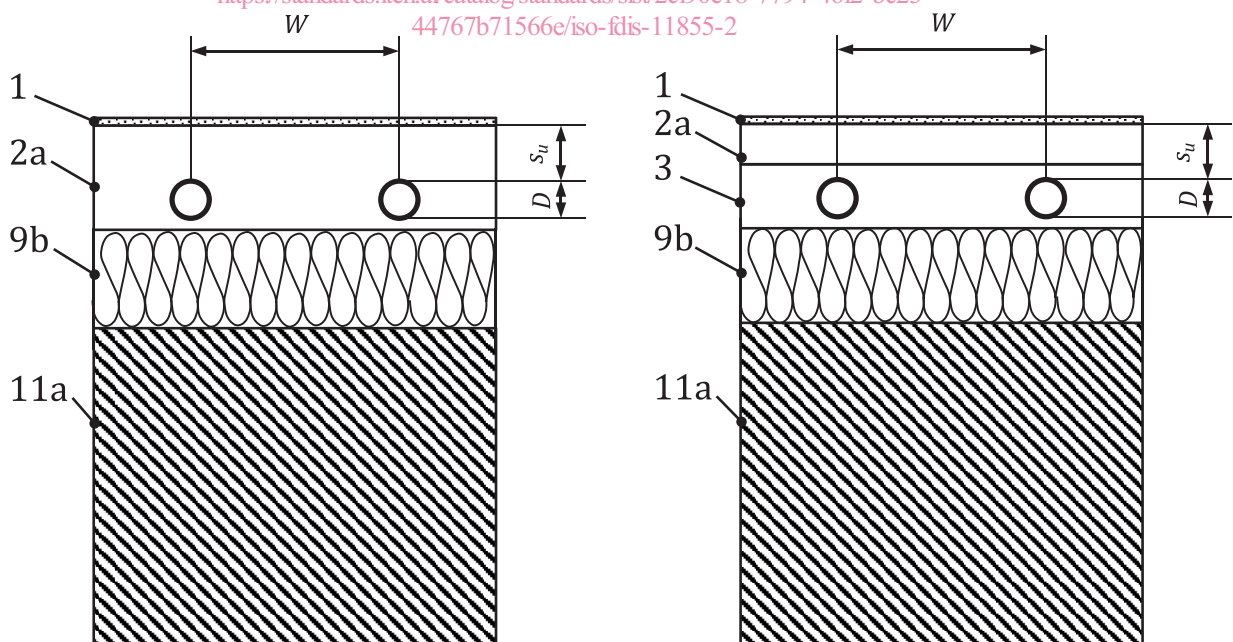
NOTE Heat flux, q , is expressed in W/m^2 .

This calculation method is given in [Annex A](#) for the following four types of systems:

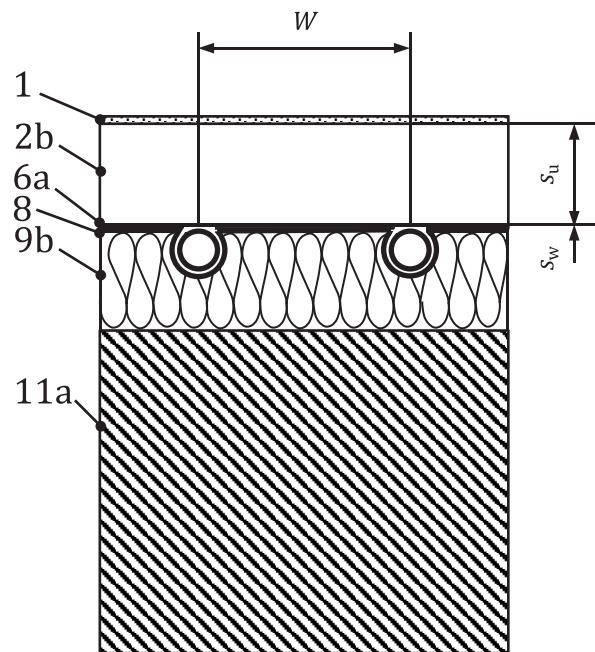
- type A with pipes embedded in the screed or concrete (see [Figure 2](#) and [A.2.2](#));
- type B with pipes embedded outside the screed (see [Figure 2](#) and [A.2.3](#));
- type C with pipes embedded in the screed (see [Figure 2](#) and [A.2.2](#));
- type D plane section systems (see [A.2.4](#)).

[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.

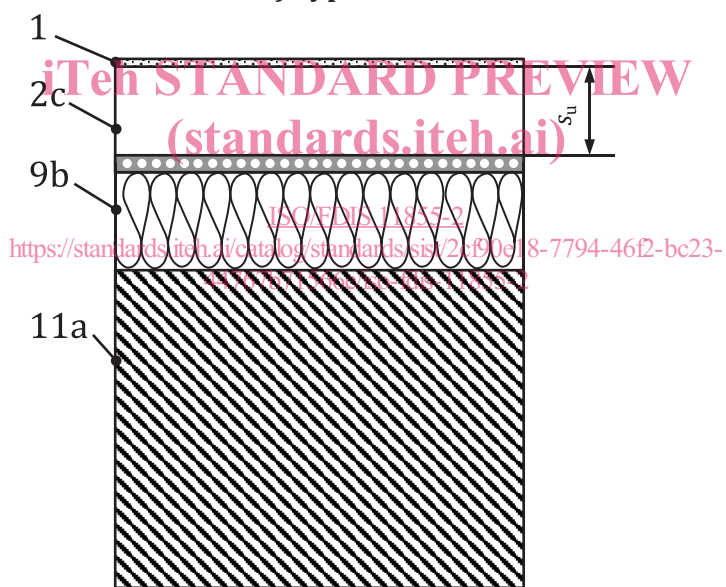
This method shall only be used for system configurations meeting the boundary conditions listed for the different types of systems in [Annex A](#).



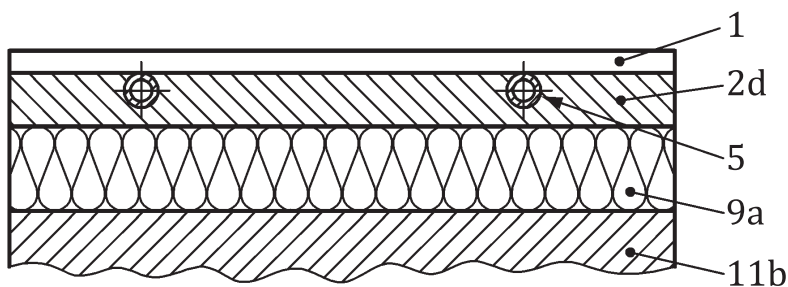
a) Type A and C



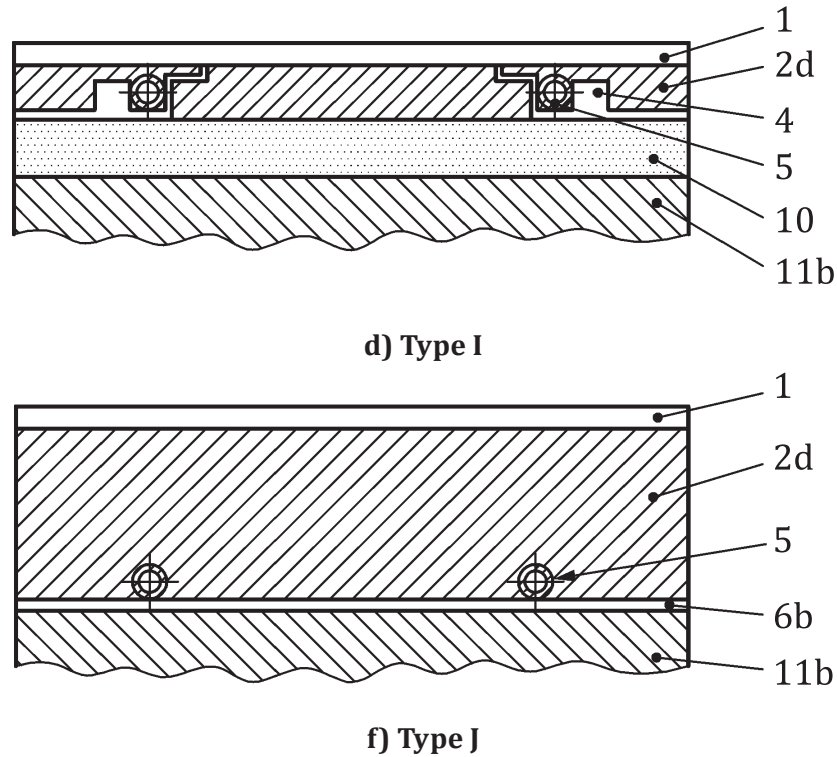
b) Type B



c) Type D



d) Type H

**Key**

- 1 floor covering
- 2a weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed)
- 2b weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed, wood)
- 2c weight bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed, timber)
- 2d weight bearing and thermal diffusion layer
- 3 adjustment layer (cement screed, anhydrite screed, asphalt screed)
- 4 profile
- 5 heating and cooling pipe
- 6a protection layer (plastic foil)
- 6b protection layer
- 7 pipe anchorage
- 8 heat diffusion devices
- 9a insulation layer
- 9b thermal insulation
- 10 adjustment layer
- 11a structural bearing
- 11b structural bearing / existing floor

Figure 2 — System types A, B, C, D, H, I and J 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](#).