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Building environment design — Embedded radiant heating and cooling systems —

Part 3: Design and dimensioning

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

Partie 3: Conception et dimensionnement

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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.

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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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 11855-3:2012), which has been technically revised.

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

— the Scope clause was modified, series-related information has been moved to the Introduction section;

— normative references were modified;

— informative references have been moved to the Bibliography;

— Annex A was added for the calculation of the thermal resistance of the insulating layers.

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 provides steady-state calculation methods for determination of the heating and cooling capacity. ISO 11855-3, this document, 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.

Building environment design — Embedded radiant heating and cooling systems —

Part 3: Design and dimensioning

1 Scope

This document establishes a system design and dimensioning method to ensure the heating and cooling capacity of the radiant heating and cooling systems.

2 Normative references

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: Definition, symbols, and comfort criteria*

ISO 11855-2:2021, *Building environment design — Embedded radiant heating and cooling systems — Part 2: Determination of the design heating and cooling capacity*

ISO 11855-5:2021, *Building environment design —Embedded radiant heating and cooling systems — Part 5: Installation*

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_F	m^2	Area of the heating or cooling surface
A_A	m^2	Area of the occupied heating or cooling surface
A_R	m^2	Area of the peripheral heating or cooling surface
C_{Wa}	J/(kg·K)	Specific heat of water
K_H	W/(m^2·K)	Equivalent heat transmission coefficient
l_p	m	Distance between the joists
l_W	m	Thickness of the joist

Table 1 *(continued)*

Symbol	Unit	Quantity
m_C	kg/s	Design cooling medium flow rate
m_H	kg/s	Design heating medium flow rate
q_{des}	W/m^2	Design heat flux
$q_{des,A}$	W/m^2	Design heat flux in the occupied area
$q_{des,R}$	W/m^2	Design heat flux in the peripheral area
q_G	W/m^2	Limit heat flux
q_{max}	W/m^2	Maximum design heat flux
Q_{des}	W	Design heating/cooling capacity
Q_N	W	Design heating/cooling load
$Q_{N,s}$	W	Design sensible cooling load
$Q_{N,l}$	W	Design latent cooling load
Q_{out}	W	Heat output of supplementary heating equipment
$R_{h,bk}$	(m^2 K)/W	Thermal resistance on the surface of the back side of the wall
$R_{h,c}$	(m^2 K)/W	Thermal resistance on ceiling surface under the floor heated room
R_o	(m^2 K)/W	Partial inwards thermal resistance of the surface structure
R_u	(m^2 K)/W	Partial outwards thermal resistance of the surface structure
$R_{\lambda,B}$	(m^2·K)/W	Thermal resistance of surface covering
$R_{\lambda,c}$	(m^2·K)/W	Thermal resistance of ceiling slab structure
$R_{\lambda,ins}$	(m^2·K)/W	Back side thermal resistance of insulating layer
$R_{\lambda,pl}$	(m^2·K)/W	Thermal resistance of plaster layer
s_{ins}	m	Effective thickness of thermal insulating layer
W	m	Pipe spacing
h_C	W/(m^2 K)	Heat transfer coefficient at ceiling heating surface
h_F	W/(m^2 K)	Heat transfer coefficient at floor heating surface
h_W	W/(m^2 K)	Heat transfer coefficient at wall heating surface
λ_{ins}	W/(m·K)	Effective thermal conductivity of the thermal insulation layer
λ_i	W/(mK)	Thermal conductivity of the thermal insulation layer between the joists
λ_w	W/(mK)	Thermal conductivity of the joist
$\theta_{F,max}$	°C	Maximum surface temperature
$\theta_{F,min}$	°C	Minimum surface temperature
θ_i	°C	Design indoor temperature
θ_R	°C	Return temperature of heating or cooling medium
θ_V	°C	Supply temperature of heating or cooling medium
$\theta_{V,des}$	°C	Design supply temperature of heating/cooling medium
$\Delta\theta_H$	K	Heating or cooling medium differential temperature
$\Delta\theta_{C,des}$	K	Design cooling medium differential temperature
$\Delta\theta_{H,des}$	K	Design heating medium differential temperature
$\Delta\theta_{H,G}$	K	Limit of heating/cooling medium differential temperature
$\Delta\theta_{V,des}$	K	Design heating/cooling medium differential supply temperature
σ	K	Temperature drop/rise between supply and return medium

5 Radiant panel

5.1 Floor heating systems

5.1.1 Design procedure

Floor heating system design requires determining heating surface area, type, pipe size, pipe spacing, supply temperature of the heating medium, and design heating medium flow rate. The design steps are as follows.

Step 1: Calculate the design heating load Q_N. The design heating load Q_N shall not include the adjacent heat losses. This step should be conducted in accordance with a standard for heating load calculation, such as EN 12831, based on an index such as operative temperature (OT) (see ISO 11855-1).

Step 2: Determine the area of the heating surface A_F, excluding any area covered by immovable objects or objects fixed to the building structure.

Step 3: Establish a maximum permissible surface temperature in accordance with ISO 11855-1.

Step 4: Determine the design heat flux q_{des} according to Formula (1). For floor heating systems including a peripheral area, the design heat flux of peripheral area $q_{des,R}$ and the design heat flux of occupied area $q_{des,A}$ shall be calculated respectively on the area of the peripheral heating surface A_R and on the area of the occupied heating surface A_A complying with Formula (2).

$$q_{des} = \frac{Q_N}{A_F} \tag{1}$$

$$Q_N = q_{des,R} \times A_R + q_{des,A} \times A_A \tag{2}$$

Step 5: For the design of the floor heating systems, determine the room used for design with the maximum design heat flux $q_{max} = q_{des}$.

Step 6: Determine the floor heating system such as the pipe spacing and the covering type, and design heating medium differential temperature $\Delta\theta_{H,des}$ based on the maximum design heat flux q_{max} and the maximum surface temperature $\theta_{F,max}$ from the field of characteristic curves according to ISO 11855-2 and 5.1.7.

Step 7: If the design heat flux q_{des} cannot be obtained by any pipe spacing for the room used for the design, it is recommended to include a peripheral area and/or to provide supplementary heating equipment. In this case, the maximum design heat flux q_{max} for the embedded system may now occur in another room. The amount of heat output of supplementary heating equipment Q_{out} is determined by Formula (3):

$$Q_{out} = Q_N - Q_{des} \tag{3}$$

where design heating capacity Q_{des} is calculated by Formula (4):

$$Q_{des} = q_{des} \times A_F \tag{4}$$

Step 8: Determine the backside thermal resistance of insulating layer $R_{\lambda,ins}$ and the design heating medium flow rate m (see 5.1.6 and 5.1.8).

Step 9: Estimate the total length of heating circuit.

If intermittent operation is common, the characteristics of the increase of the heat flow and the surface temperature and the time to reach the allowable conditions in rooms just after switching on the system shall be considered.

5.1.2 Heating medium differential temperature

Heating medium differential temperature $\Delta\theta_H$ is calculated as follows (refer to ISO 11855-2):

$$\Delta\theta_H = \frac{\theta_V - \theta_R}{\ln \dfrac{\theta_V - \theta_i}{\theta_R - \theta_i}} \qquad (5)$$

In this formula, the effect of the temperature drop of the heating medium is taken into account.

5.1.3 Characteristic curve

The characteristic curve describes the relationship between the heat flux q and the heating medium differential temperature $\Delta\theta_H$. For simplicity, the heat flux q is taken to be proportional to the heating medium differential temperature $\Delta\theta_H$:

$$q = K_H \cdot \Delta\theta_H \qquad (6)$$

where K_H is the equivalent heat transmission coefficient determined in ISO 11855-2 depending on the type of the system.

5.1.4 Field of characteristic curves

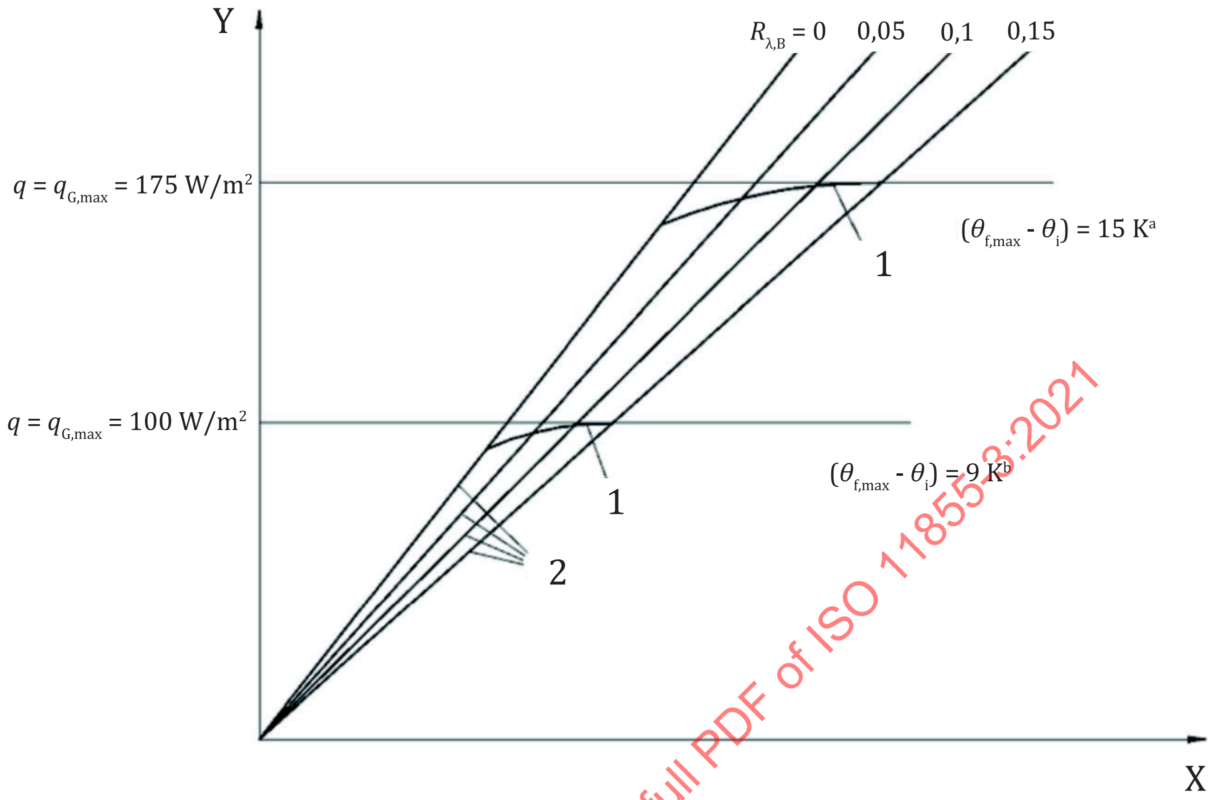
The field of characteristic curves of a floor heating system with a specific pipe spacing W shall at least contain the characteristic curves for values of the thermal resistance of surface covering $R_{\lambda,B}$ = 0, $R_{\lambda,B}$ = 0,05, $R_{\lambda,B}$ = 0,10 and $R_{\lambda,B}$ = 0,15 (m^2K/W), in accordance with ISO 11855-2 (see Figure 1). Values of $R_{\lambda,B}$ > 0,15 (m^2K/W) shall not be used if possible.

5.1.5 Limit curves

The limit curves in the field of characteristic curves describe, in accordance with ISO 11855-2, the relationship between the heating medium differential temperature $\Delta\theta_H$ and the heat flux q in the case where the physiologically agreed limit values of surface temperatures are reached. For design purposes, i.e. the determination of design values of the heat flux and the associated heating medium differential temperature $\Delta\theta_H$, the limit curves are valid for temperature drop between supply and return medium σ in a range of:

$$0\ \text{K} < \sigma < 5\ \text{K}$$

The limit curves are used to specify the limit of heating medium differential temperature $\Delta\theta_{H,G}$ and supply temperature (refer to Figure 6).



Key

X $\Delta\theta_H$ K

Y q W/m²

1 limit curves

2 performance characteristic curves

a Peripheral area.

b Occupied area.

Figure 1 — Field of characteristic curves, including limit curves for floor heating, for constant pipe spacing

This example is for floor heating, indoor temperature = 20 °C and the maximum temperature is 29 °C (occupied areas) and 35 °C (peripheral area). For bathrooms (the indoor temperature is 24 °C), the limit curve for $(\theta_{F,max} - \theta_i)$ = 9 K also applies.

5.1.6 Downwards thermal insulation

In order to limit the heat flow through the floor towards the space below, the required back-side thermal resistance of the insulating layer $R_{\lambda,ins}$ shall be specified in the design to be not lower than the value in ISO 11855-5:2021, 5.1.2.3.2.

For systems which have a flat insulating layer (types A, B, C, D and G in ISO 11855-2), the back-side thermal resistance of the insulating layer $R_{\lambda,ins}$ is calculated by Formula (7) where there is no stud. And the effective thickness of thermal insulating layer s_{ins} is identical to the thickness of the thermal insulating panel and the effective thermal conductivity of the thermal insulation layer λ_{ins} is calculated by Formula (7) where there are studs.

$$R_{\lambda,ins} = \frac{s_{ins}}{\lambda_{ins}} \qquad (7)$$

$$\lambda_{ins} = \lambda_i \frac{l_p - l_{ws}}{l_{ps}} + \lambda_{ws} \frac{l_{ws}}{l_{ps}} \tag{8}$$

where

λ_i is thermal conductivity of the thermal insulation layer between the studs;

λ_{ws} is thermal conductivity of the stud;

l_{ps} is the distance between the studs (see Figure 2);

l_{ws} is the thickness of the stud (see Figure 2).

Depending on the construction of the floor heating system, the effective thickness of thermal insulating layer s_{ins} and effective thermal conductivity of the thermal insulation layer λ_{ins} are determined differently.

For floor heating systems with flat thermal insulating panels of types A and C in ISO 11855-2, the effective thickness of thermal insulating layer s_{ins} is identical to the thickness of the thermal insulation, and the effective thermal conductivity of the thermal insulation layer λ_{ins} is identical to the thermal conductivity of the thermal insulation [ISO 11855-2:2021, Figure 2 a)]. For floor heating systems with thermal insulation panels with studs according to Annex A (type A and type C systems) (Figure A.1), only the flat part of the panel (without studs) shall be considered in the calculation of s_{ins}.

For the system with profiled thermal insulating panels of type B in ISO 11855-2:2021, Figure 2 b), the effective thickness of the insulating layer shall be determined by Formula (9).

$$s_{ins} = \frac{s_h \cdot (W - D) + s_l \cdot D}{W} \tag{9}$$

For the system with the light wooden radiant panel on the joist of type G in ISO 11855-2:2021, Figure 2 c), the effective thickness of thermal insulating layer s_{ins} is identical to the thickness of the thermal insulating panel, and the effective thermal conductivity of the thermal insulation layer λ_{ins} is:

$$\lambda_{ins} = \lambda_i \frac{l_p - l_w}{l_p} + \lambda_w \frac{l_w}{l_p} \tag{10}$$

where

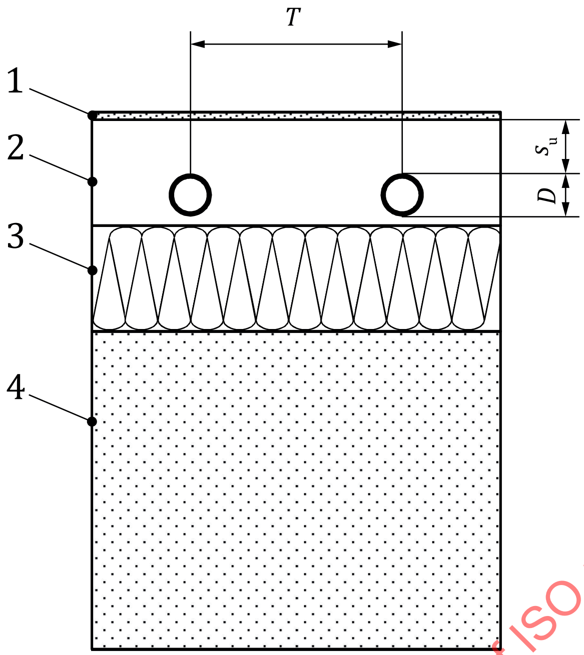
λ_i is thermal conductivity of the thermal insulation layer between the joists;

λ_w is thermal conductivity of the joist;

l_p is the distance between the joist (see Figure 5);

l_w is the thickness of the joist (see Figure 5).

For type G systems with air cavities, see ISO 11855-2:2021, Annexes C and E.



Key

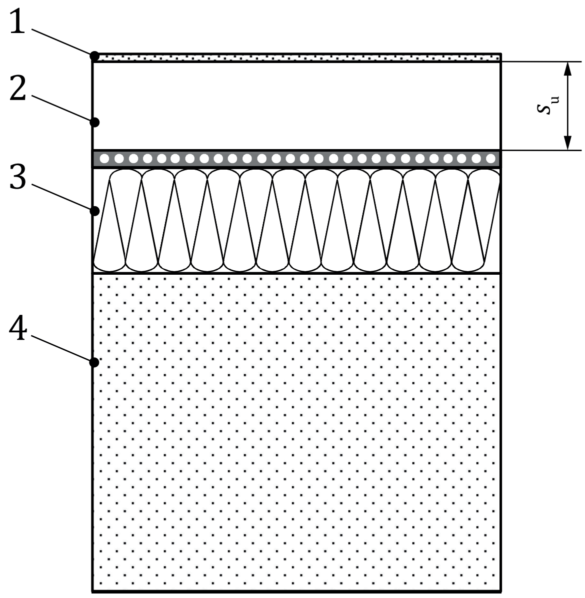
1 floor covering

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

3 thermal insulation

4 structural bearing

Figure 2 — Effective thickness and effective thermal conductivity of thermal insulating layer of flat thermal insulating panel — Types A and C



Key

1 floor covering

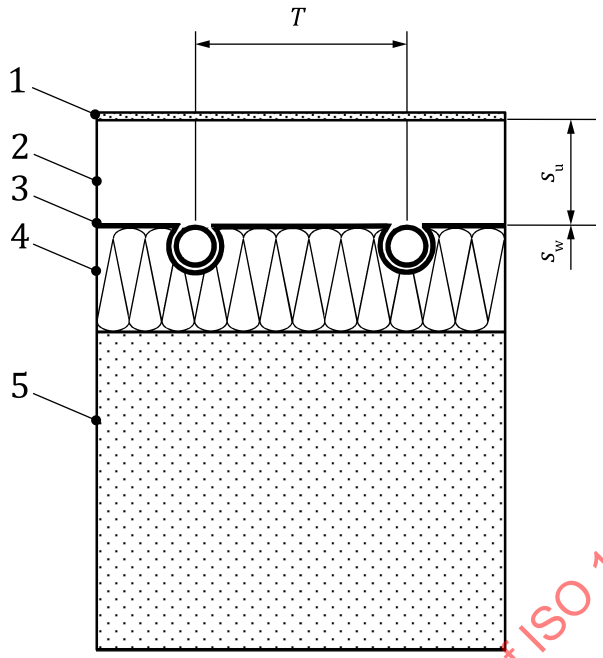
2 weight bearing and thermal diffusion layer (cement, anhydrite, or asphalt screed)

3 plane section

4 thermal insulation

5 structural bearing

Figure 3 — Effective thickness and effective thermal conductivity of thermal insulating layer of flat thermal insulating panel — Type D



Key

1 floor covering

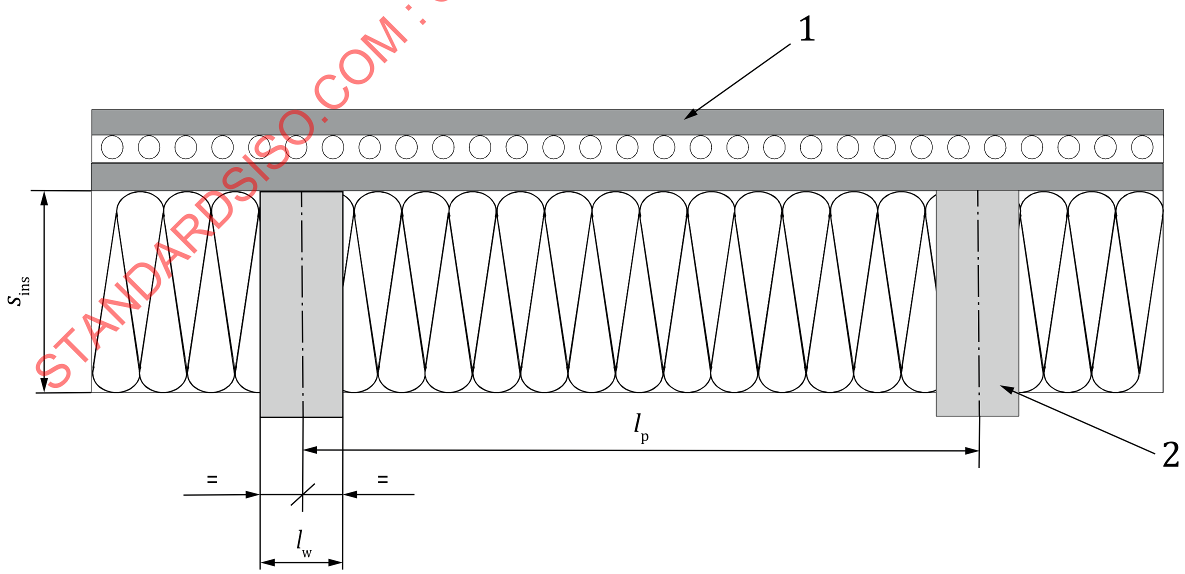
2 weight bearing and thermal diffusion layer (cement, anhydrite, or asphalt screed; timber)

3 heat diffusion devices

4 thermal insulation

5 structural bearing

Figure 4 — Effective thickness and effective thermal conductivity of thermal insulating layer of profiled thermal insulating panel — Type B



Key

1 floor covering

2 joist

Figure 5 — Effective thickness and effective thermal conductivity of thermal insulating layer of flat thermal insulating panel with joist — Type G

National building codes provide minimum thermal resistances for the insulating layers of floor heating.

5.1.7 Procedure for determining the design supply temperature of the heating medium

The design supply temperature of the heating medium $\theta_{V,des}$ is determined for the room where the maximum design heat flux q_{max} is equal to the design heat flux q_{des}. In heating rooms, thermal conduction resistance of floor coverings (carpet, tiles, acoustic plates, etc.) is assumed to be uniformly distributed. The thermal resistance of the floor coverings used for the design shall be specified. For the room used for design, the temperature drop between supply and return medium $\sigma \leq 5$ K is specified. If necessary, a subdivision of the room into heating circuits shall be performed. Under these conditions, the maximum design heat flux q_{max} may reach until the limit heat flux q_G (see Figure 6).

For the room with the maximum design heat flux q_{max}, a pipe spacing is chosen with which q_{max} remains less than or equal to the limit heat flux q_G, specified by the limit curves: ($q_{max} \leq q_G$; see Figure 6). In case of $q_{max} < q_G$, design heating medium differential supply temperature is $\Delta\theta_{V,des} \leq \Delta\theta_{H,G} + 2{,}5$ K. The maximum permissible design heating medium differential supply temperature is determined by Formula (11):

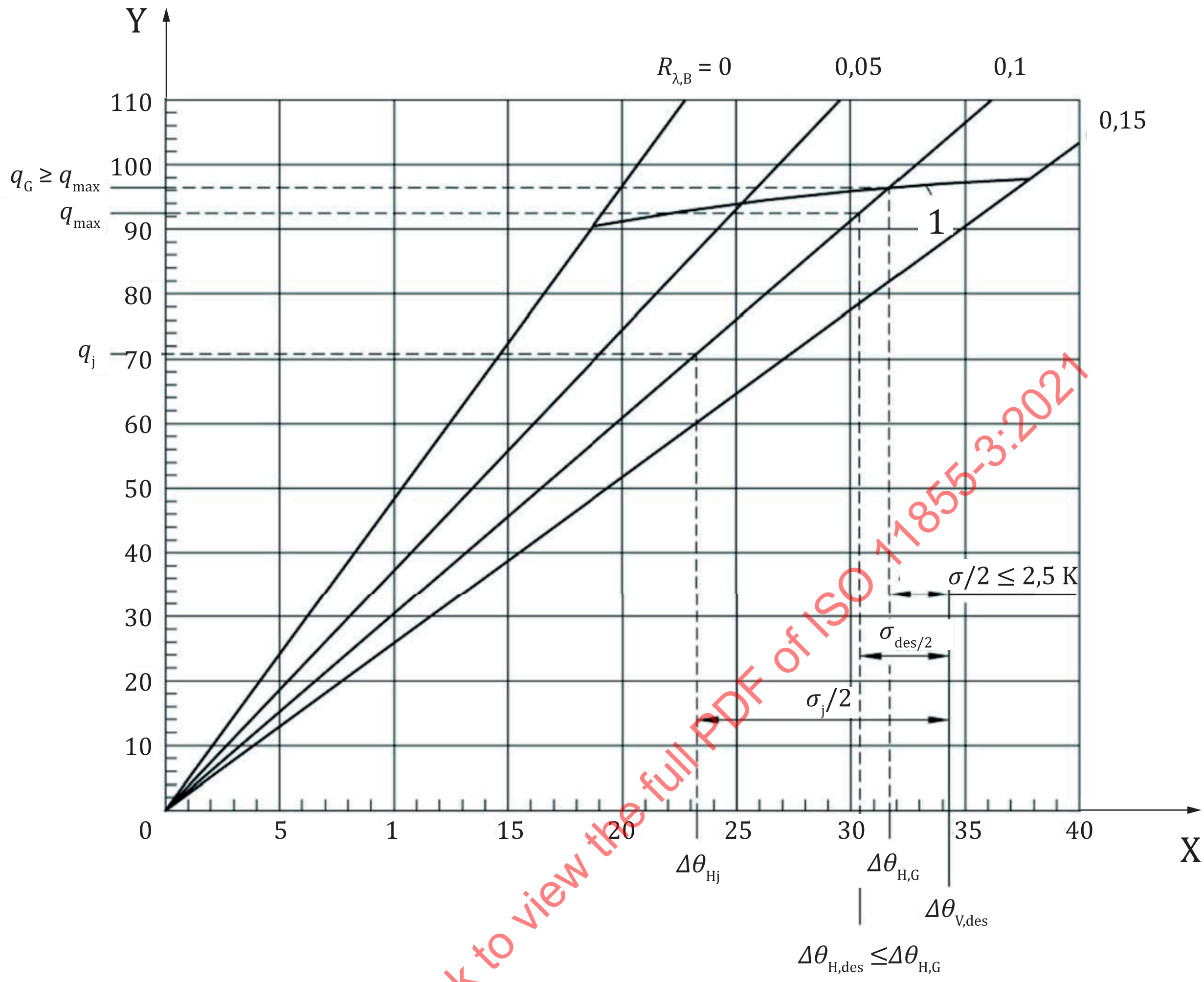
$$\Delta\theta_{V,des} = \Delta\theta_{H,des} + \frac{\sigma}{2} \tag{11}$$

where $\Delta\theta_{H,des} \leq \Delta\theta_{H,G}$.

Formula (11) applies if $\sigma/\Delta\theta_H \leq 0{,}5$. For the ratio $(\sigma/\Delta\theta_H) > 0{,}5$, the following applies:

$$\Delta\theta_{V,des} = \Delta\theta_{H,des} + \frac{\sigma}{2} + \frac{\sigma^2}{12\Delta\theta_{H,des}} \tag{12}$$

The temperature drop σ in Formulae (11) and (12) in Figure 3 is designated to be σ_{des}.



Key

X $\Delta\theta_H$

Y q

1 limit curve

Figure 6 — Determination of the design supply temperature difference and temperature drop σ_j for the other rooms

The result of Formula (11) or (12) provides the design supply temperature $\theta_{V,des}$ as in Formula (13).

$$\theta_{V,des} = \Delta\theta_{V,des} + \theta_i \quad (13)$$

For all other rooms operated at the same supply temperature $\theta_{V,des}$, the associated temperature drops for determining the water flow for $(\sigma_j/\Delta\theta_{H,j}) < 0{,}5$ shall be plotted from the field of characteristic curves (see Figure 6) or calculated according to Formula (14) and (15), which are expressed by the heating medium differential temperatures $\Delta\theta_{H,j}$ corresponding to the respective values of the heat flux q_j.

$$\frac{\sigma_j}{2} = \left(\theta_{V,des} - \left(\Delta\theta_{H,j} + \theta_j\right)\right) \quad (14)$$

$$\sigma = 3\Delta\theta_{H,j}\left[\left(1+\frac{4\left(\theta_{V,des}-\left(\Delta\theta_{H,j}+\theta_j\right)\right)}{3\Delta\theta_{H,j}}\right)\right] \quad (15)$$

For $(\sigma_j / \Delta\theta_{H,j}) > 0{,}5$, the temperature drop σ_j is calculated as follows.

NOTE Formulae (11) and (14) are the result of simplifications and therefore, they are valid only under the specific condition, $\sigma / \Delta\theta_H \leq 0{,}5$. Compared to this, Formulae (12) and (15) generally are applicable, i.e. for any relationship, $\sigma / \Delta\theta_H$.

If the design heat flux q_{des} cannot be obtained under the aforementioned conditions by any pipe spacing for the room used for the design, it is recommended to include a peripheral area and/or to provide alternative additional heating surfaces. The additional heating surfaces shall be selected to suit the purpose and location. In this case, the maximum design heat flux q_{max} for the embedded system may now occur in another room.

$\theta_{V,des}$ could be directly determined using the analytical solution of Formula (5) .

$$\Delta\theta_{H,des} = \frac{\left(\theta_{V,des}-\theta_{R,des}\right)}{\ln\left(\frac{\left(\theta_{V,des}-\theta_i\right)}{\left(\theta_{R,des}-\theta_i\right)}\right)} = \frac{\sigma}{\ln\left(\frac{\left(\theta_{V,des}-\theta_i\right)}{\left(\theta_{V,des}-\sigma-\theta_i\right)}\right)} \quad (16)$$

Since we know $\Delta\theta_{H,des}$, θ_i and σ, we can solve the formula.

So we have:

$$\theta_{V,des} = \frac{\left(\theta_i - (\sigma+\theta_i)\cdot\exp\left(\frac{\sigma}{\Delta\theta_{H,des}}\right)\right)}{\left(1-\exp\left(\frac{\sigma}{\Delta\theta_{H,des}}\right)\right)} \quad (17)$$

This could be simplified by the following formula when $\frac{\sigma}{\Delta\theta_{H,des}} \leq 0{,}5$

$$\theta_{V,des} = \Delta\theta_{H,des} + \theta_i + \frac{\sigma}{2} \quad (18)$$

Then we have

$$\theta_{R,des} = \theta_{V,des} - \sigma \quad (19)$$

To find $\theta_{R,j}$ directly for all other rooms, use the formulae shown below:

$$\Delta\theta_{H,j} = \left(\frac{(\theta_{V,j} - \theta_j)^{\frac{1}{3}} + (\theta_{R,j} - \theta_j)^{\frac{1}{3}})}{2}\right)^3 \quad (20)$$

Since $\theta_{V,j} = \theta_{V,des}$

We have:

$$\theta_{R,j} = \theta_j + \left(2\cdot\Delta\theta_{H,j}^{\frac{1}{3}} - (\theta_{V,des} - \theta_j)^{\frac{1}{3}}\right)^3 \quad (21)$$

Therefore,

$$\sigma = \theta_{V,des} - \theta_{R,j} \quad (22)$$

5.1.8 Procedure for determining the design heating medium flow rate

It is recommended to design for the same flow rate for heating and for cooling. In this way, no adjustments of balancing valves are required when switching between heating and cooling. One way to change the flow rate between heating and cooling is to apply a circulation pump with different settings. The design heating medium flow rate *m* of a surface heating circuit is calculated as follows (see Figure 7):

$$m_H = \frac{A_F \cdot q}{\sigma \cdot c_{Wa}} \left(1 + \frac{R_o}{R_u} + \frac{\theta_i - \theta_u}{q \cdot R_u} \right) \quad (23)$$

c_{Wa} is the specific heat capacity of water; $c_{Wa} = 4\,190$ J/(kg·K)
(using this value together with q in W/m^2 in Formula (23), m is provided in kg/s);

R_o is the upwards partial heat transmission resistance of the floor structure [see Formula (24)];

R_u is the downwards partial heat transmission resistance of the floor structure [see Formula (25)];

θ_i is the standard indoor room temperature in accordance with ISO 11855-2;

θ_u is the indoor temperature of a room under the floor heated room.

With respect to the thermal resistances indicated in Figure 7, the following formulae are valid, and back side thermal resistance of insulating layer for type A and C is calculated by Annex A.

$$R_o = \frac{1}{h_F} + R_{\lambda,B} + \frac{s_u}{\lambda_u} \quad (24)$$

$$R_u = R_{\lambda,ins} + R_{\lambda,c} + R_{\lambda,pl} + R_{h,c} \quad (25)$$

where

$1/h_F$ is the thermal resistance on the heating floor surface; $1/h_F$ = 0,0 093 (m^2·K)/W;

$R_{\lambda,pl}$ is the thermal resistance of the plaster;

$R_{h,c}$ is the thermal resistance on the ceiling under the floor heated room; $R_{h,c}$ = 0,17 (m^2·K)/W.

NOTE The calculation procedure above described on the basis of Figure 7 is to be understood as a principle one. For other structures, an appropriate modification can be necessary.

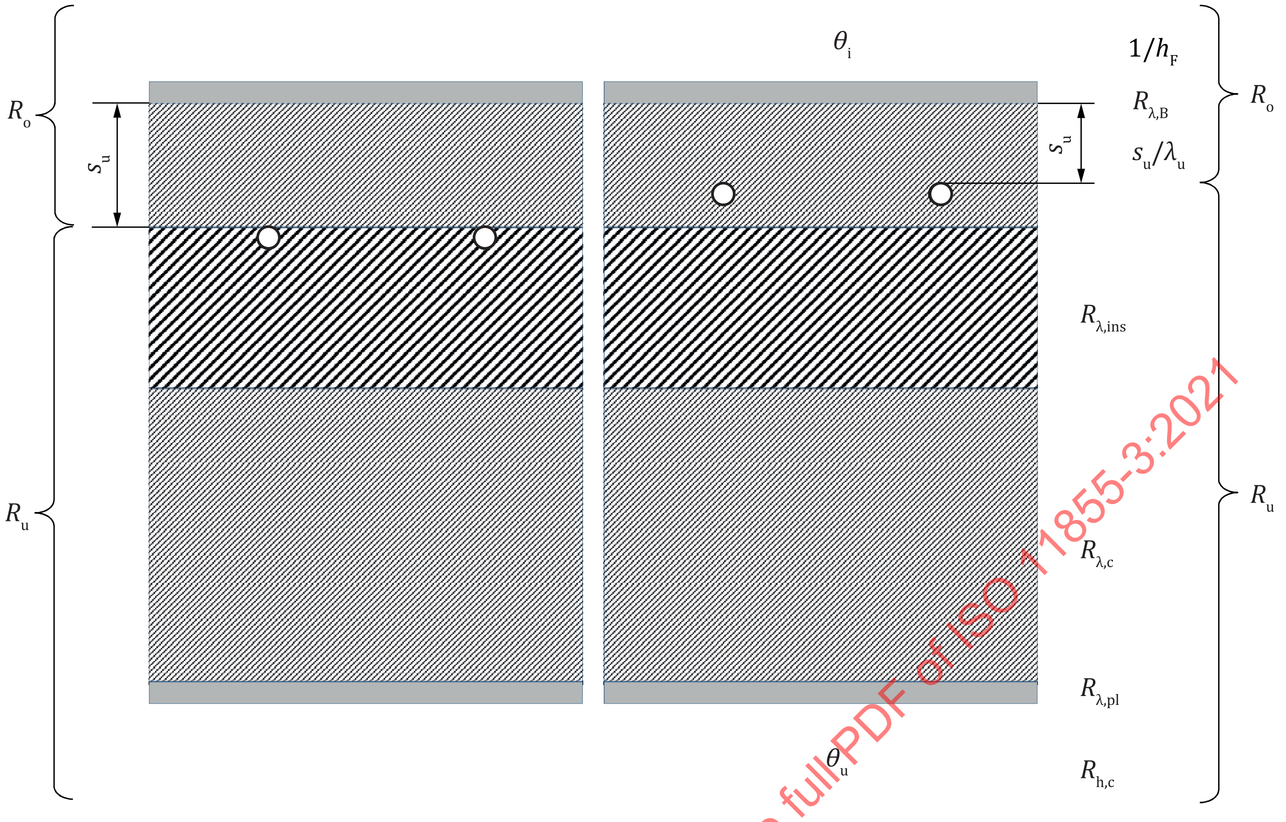


Figure 7 — Model of a floor construction with floor heating system installed

The partial inwards heat transmission resistance of the surface structure R_o covers the inward heat conduction and heat transmission resistances, and the partial outwards heat transmission resistance of the surface structure R_u covers the back-side heat conduction and heat transmission resistances (refer to R_o and R_u in ISO 11855-2:2021, Annexes A and B).

5.1.9 Peripheral areas

The area of the peripheral heating surface A_R with an increased surface temperature (for example up to a maximum of 35 °C) is generally situated along the outer walls of a room with a maximum width of 1 m. As described in 5.1.5, design of peripheral areas is based on the higher limit curve, $\theta_{F,max} - \theta_i = 15$ K (see Figure 1). In case a series circuit is formed with a heating circuit in the occupied area, the temperature drop in the peripheral area shall be selected so that the supply temperature, calculated from the lower limit curve, is not exceeded by entry of the heating medium from the peripheral area into the occupied area.

5.2 Ceiling heating systems

5.2.1 General

It is recommended to apply the descriptions for floor heating system given in 5.1 for ceiling heating system accordingly (in the respective wordings replace “floor heating” by “ceiling heating”) with exception of 5.1.5 for limit curves.

5.2.2 Limit curves

Physiological limitations concerning the surface temperatures of ceiling heating systems depend on geometrical conditions, i.e. in practice on the respective application. Therefore, in this document, only average conditions can be taken into consideration. Consequently, it is emphasized that in practical engineering the real conditions shall be taken into account.

