BS EN ISO 11855-3:2015

BSI Standards Publication

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

Part 3: Design and dimensioning

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National foreword

This British Standard is the UK implementation of EN ISO 11855-3:2015. It is identical to ISO 11855-3:2012.

The UK participation in its preparation was entrusted to Technical Committee RHE/24, Central heating installations.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Conception de l'environnement des bâtiments - Normes pour la conception, la construction et le fonctionnement des systèmes de chauffage et de refroidissement par rayonnement - Partie 3: Conception et dimensionnement (ISO 11855-3:2012)

Umweltgerechte Gebäudeplanung - Planung, Auslegung, Installation und Steuerung flächenintegrierter Strahlheizungs- und -kühlsysteme - Teil 3: Planung und Auslegung (ISO 11855-3:2012)

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European foreword

The text of ISO 11855-3:2012 has been prepared by Technical Committee ISO/TC 205 “Building environment design” of the International Organization for Standardization (ISO) and has been taken over as EN ISO 11855-3:2015 by Technical Committee CEN/TC 228 “Heating systems and water based cooling systems in buildings” the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by February 2016, and conflicting national standards shall be withdrawn at the latest by February 2016.

This standard is applicable for design, construction and operation of radiant heating and cooling systems. The methods defined in part 2 are intended to determine the design heating or cooling capacity used for the design and evaluation of the performance of the system.
For identifying product characteristics by testing and proving the thermal output of heating and cooling surfaces embedded in floors, ceilings and walls the standard series EN 1264 can be used.

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The text of ISO 11855-3:2012 has been approved by CEN as EN ISO 11855-3:2015 without any modification.

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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.

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ISO 11855-3 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.

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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.

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

Part 3:
Design and dimensioning

1 Scope

This part of ISO 11855 establishes a system design and dimensioning method to ensure the heating and cooling capacity of the radiant heating and cooling systems.

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 applies also, 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.

EN 12831, *Heating systems in buildings — Method for calculation of the design heat load*

EN 15243, *Ventilation for buildings — Calculation of room temperatures and of load and energy for buildings with room conditioning systems*

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

ISO 11855-2, *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*

3 Terms and definitions

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

4 Symbols and abbreviated terms

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

Table 1 — Symbols and abbreviated terms

Symbol	Unit	Quantity
A_F	m^2	Area of the heating/cooling surface

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Table 1 *(continued)*

Symbol	Unit	Quantity
A_A	m^2	Area of the occupied heating/cooling surface
A_R	m^2	Area of the peripheral heating/cooling surface
c_W	J/(kg·K)	Specific heat of medium
K_H	$W/(m^2 \cdot K)$	Equivalent heat transmission coefficient
l_p	m	Distance between the joists
l_W	m	Thickness of the joist
M	kg/s	Design heating/cooling 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_o	$(m^2\ K)/W$	Partial inwards heat transmission resistance of the surface structure
R_u	$(m^2\ K)/W$	Partial outwards heat transmission resistance of the surface structure
$R\lambda_{,B}$	$(m^2 \cdot K)/W$	Thermal resistance of surface covering
$R\lambda_{,ins}$	$(m^2 \cdot K)/W$	Back side thermal resistance of insulating layer
s_{ins}	m	Effective thickness of thermal insulating layer
W	m	Pipe spacing
h	$W/(m^2\ K)$	Heat transfer coefficient
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/cooling medium
θ_V	°C	Supply temperature of heating/cooling medium
$\theta_{V,des}$	°C	Design supply temperature of heating/cooling medium
$\Delta\theta_H$	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
$\Delta\theta_{V,des}$	K	Design heating/cooling medium differential supply temperature
σ	K	Temperature drop/rise between supply and return medium

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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 Equation (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 Equation (2).

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

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

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 in this part of ISO 11855.

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 the following equation:

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

where design heating capacity Q_{des} is calculated by:

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

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.

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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):

$$\Delta\theta_H = \frac{\theta_V - \theta_R}{\ln \dfrac{\theta_V - \theta_i}{\theta_R - \theta_i}} \tag{5}$$

In this equation, 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 $\Delta\theta_H$:

$$q = K_H \cdot \Delta\theta_H \tag{6}$$

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

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^{2}K/W), in accordance with ISO 11855-2 (see Figure 1). Values of $R_{\lambda,B}$ > 0,15 (m^{2}K/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 $\Delta\theta$, the limit curves are valid for temperature drop between supply and return medium σ in a range of:

$$0\ \text{K} < \sigma < 5\ \text{K} \tag{7}$$

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).

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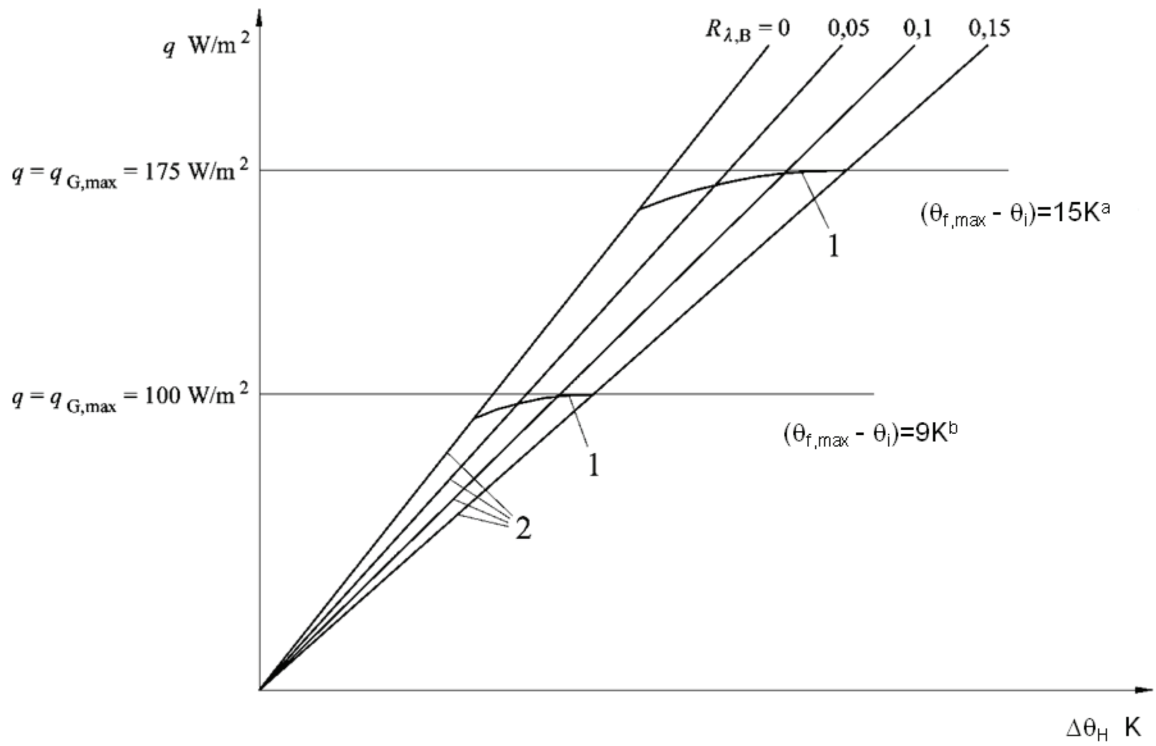

Key

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 ($\theta_{F,max} - \theta_i$) = 9K 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 Table 2 in ISO 11855-4:2012.

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 Equation (8).

$$R_{\lambda,ins} = \frac{s_{ins}}{\lambda_{ins}} \qquad (8)$$

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 11855-2:2012, 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 [Figure 2 a)].

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For the system with profiled thermal insulating panels of type B in ISO 11855-2:2012 [Figure 2 b)], the effective thickness of the insulating layer shall be determined by Equation (9).

$$s_{\text{ins}} = \frac{s_{\text{h}} \cdot (W - D) + s_{\text{l}} \cdot D}{W} \tag{9}$$

For the system with the light wooden radiant panel on the joist of type G in ISO 11855-2:2012 [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:

$$\lambda_{\text{ins}} = \lambda_{\text{i}} \frac{l_{\text{p}} - l_{\text{w}}}{l_{\text{p}}} + \lambda_{\text{w}} \frac{l_{\text{w}}}{l_{\text{p}}} \tag{10}$$

where:

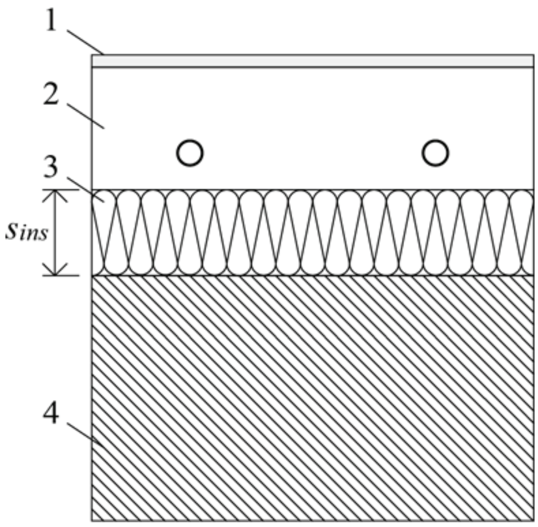
λ_{i} is thermal conductivity of the thermal insulation layer between the joists;

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 Annex C and E in ISO 11855-2:2012.



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

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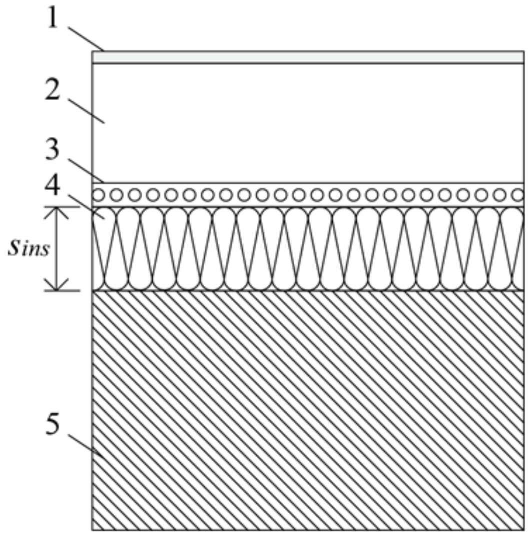
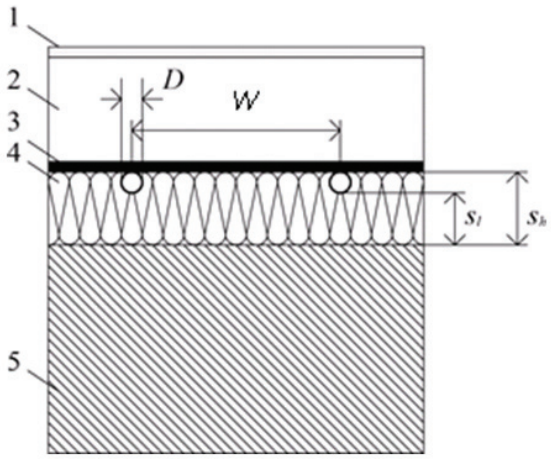


Key

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

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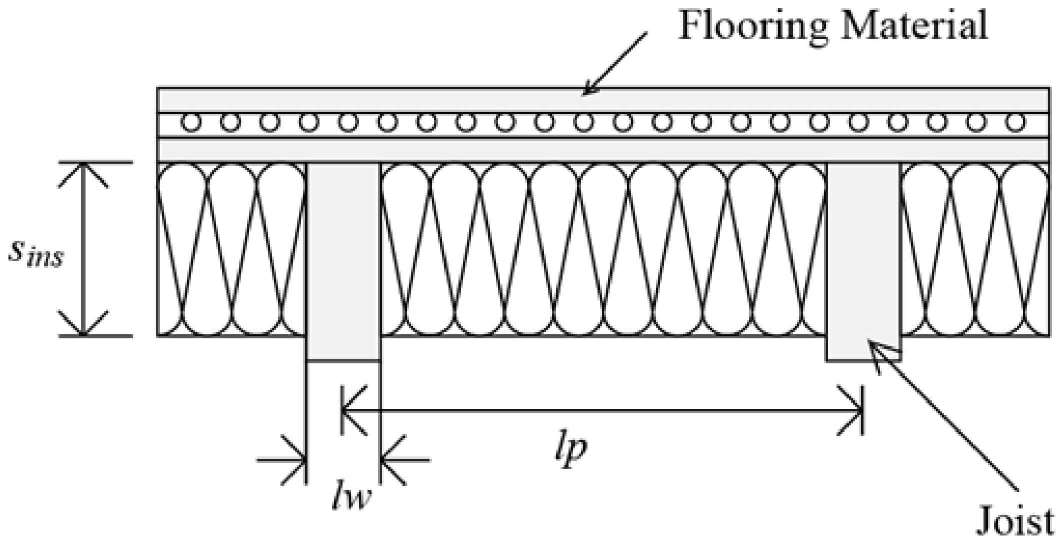

Figure 5 — Effective thickness and effective thermal conductivity of thermal insulating layer of flat thermal insulating panel with joist — Type G

The insulating layers of a floor heating shall comply with the minimum thermal resistances given in national building codes.

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

The design supply temperature of the heating medium $\theta_{V,des}$ is determined for the room with the maximum design heat flux $q_{max} = q_{des}$. In the rooms being heated, it is assumed that floor coverings (carpet, tiles, acoustic plates, etc.) with a uniform thermal conduction resistance are used. The thermal resistance of the covering used for the design shall be documented. For the room used for design, the temperature drop between supply and return medium $\sigma \leq 5K$ 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 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 Equation 11:

$$'' \theta_{V,des} = '' \theta_{H,des} + \frac{\sigma}{2} \qquad (11)$$

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

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

$$'' \theta_{V,des} = '' \theta_{H,des} + \frac{\sigma}{2} + \frac{\sigma^2}{12'' \theta_{H,des}} \ \text{K} \qquad (12)$$

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

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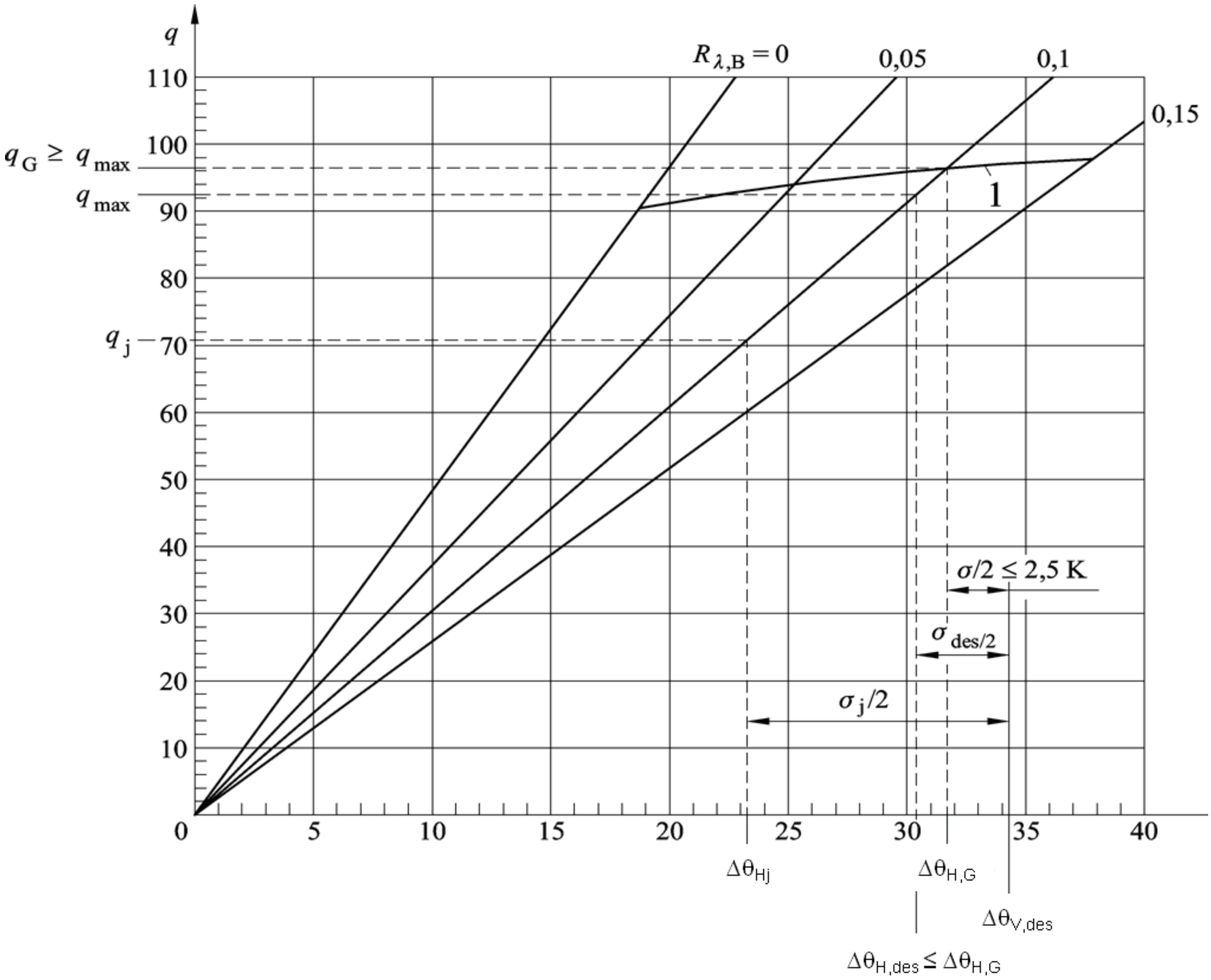

Key

1 limit curve

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

The result of Equation (11) or (12) provides the design supply temperature, $\theta_{V,des} = " \theta_{V,des} + \theta_i$.

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:

$$\frac{\sigma_j}{2} = \Delta\theta_{V,des} - \Delta\theta_{H,j} \tag{13}$$

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$$\sigma = 3''\ \theta_{H,j}\left[\left(1+\frac{4\left(''\ \theta_{V,des}-''\ \theta_{H,j}\right)}{3''\ \theta_{H,j}}\right)^{\frac{1}{2}}-1\right]\ \mathrm{K} \qquad (14)$$

using the heating medium differential temperatures $\Delta\theta_{H,j}$ corresponding to the respective values of the heat flux q_j. For $(\sigma_j / \Delta\theta_{H,j}) > 0,5$, the temperature drop σ_j is calculated as follows.

NOTE Equations (11) and (13) are the result of simplifications and therefore they are valid only under the specific condition, $\sigma /''\ \theta_H \leq 0{,}5$. Compared to this, Equations (12) and (14) generally are applicable, i.e. for any relationship, $\sigma /''\ \theta_H$.

If the value 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.

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, etc., 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):

$$m = \frac{A_F \cdot q}{\sigma \cdot c_W}\left(1+\frac{R_o}{R_u}+\frac{\theta_i-\theta_u}{q \cdot R_u}\right) \qquad (15)$$

c_W is the specific heat capacity of water; c_W = 4 190 J/(kg·K) Using this value together with q in W/m^2 in Equation (15), m is provided in kg/s.;

R_o is the upwards partial heat transmission resistance of the floor structure [see Equation (16)];

R_u is the downwards partial heat transmission resistance of the floor structure [see Equation (17)];

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 equations are valid:

$$R_o = \frac{1}{h} + R_{\lambda;B} + \frac{s_u}{\lambda_u} \qquad (16)$$

$$R_u = R_{\lambda,ins} + R_{\lambda,ceiling} + R_{\lambda,plaster} + R_{h,ceiling} \qquad (17)$$

where:

1/h is the heat transfer resistance on the heating floor surface; 1/h = 0,0 093 (m^2·K)/W;

$R_{h,ceiling}$ is the heat transfer resistance on the ceiling under the floor heated room; $R_{h,ceiling}$ = 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 may be necessary.

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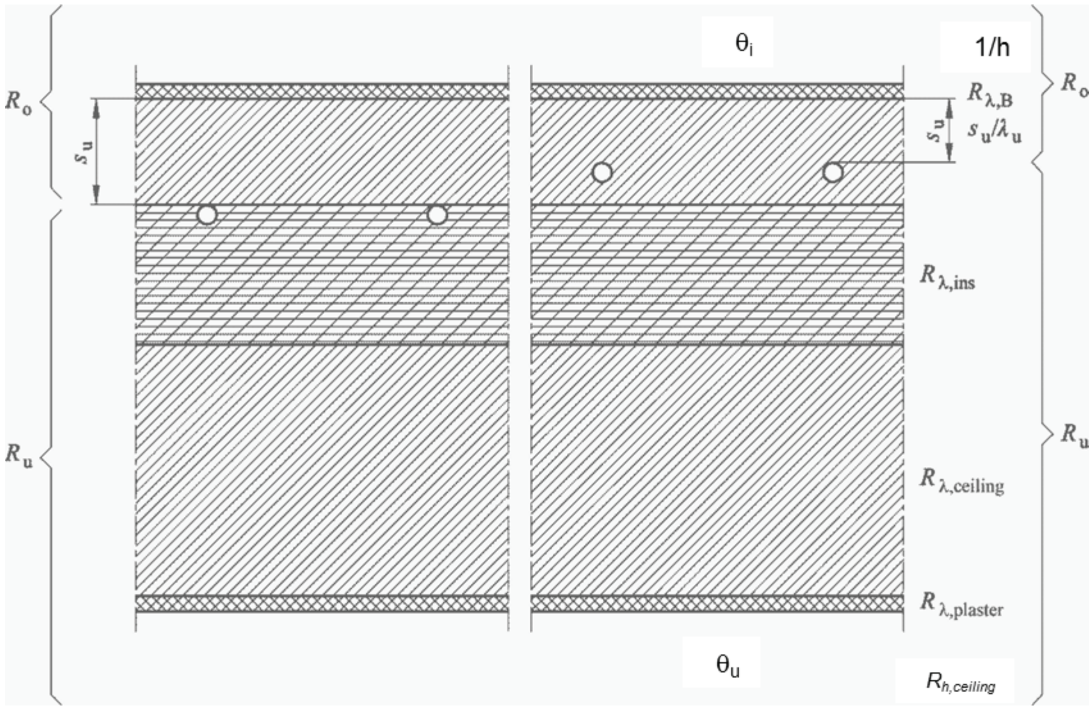

Figure 7 — Model of a floor construction with floor heating system installed

The partial inwards heat transmission resistance of the surface structure R_0 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_0 and R_u in Annexes A and B in ISO 11855-2:2012).

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 part of ISO 11855, only average conditions can be taken into consideration. Consequently it is emphasized that in practical engineering the real conditions shall be taken into account.

For geometrical conditions of usual flat rooms, a maximum amount for the average temperature of the ceiling heating surface shall be decided based on the asymmetry of the surface temperature between the ceiling surface and the other parts surface (refer to ISO 11855-1), e.g. $\theta_{F,m}$ = 33 °C is applicable,

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where the difference of the temperature between the heating surface and the room is 13K. As a result, the limit curve within the field of characteristic curves is a horizontal straight line and q_G is 85 (W/m^2), assuming that h = 6,5 (W/m^{2}K), based on ISO 11855-2.

If higher values $\theta_{F,m}$ > 33 °C are used, the compliance with physiological limitations shall be proved.

5.2.3 Procedure for determining the design heating medium flow rate

It is recommended to apply the procedure described in 5.1.8 accordingly taking into account the reversed position of the structure shown in Figure 7 and the changes of the transfer resistances on the surfaces as follows:

1/h is the heat transfer resistance on the heating ceiling surface; 1/α = 0,154 (m^2·K)/W;

$R_{h,ceiling}$ is replaced by $R_{h,floor}$, the heat transfer resistance on the floor above the ceiling heated room; $R_{h,floor}$ = 0,10 (m^2·K)/W.

5.3 Wall heating systems

5.3.1 General

It is recommended to apply the descriptions for floor heating systems given in 5.1 for wall heating system accordingly (in the respective wordings replace "floor heating" by "wall heating") with the exception of 5.1.5 for limit curve.

5.3.2 Limit curves

Physiological limitations concerning the surface temperatures of wall heating systems depend on geometrical conditions, i.e. in practice on the respective application. Therefore, in this part of ISO 11855 only average conditions can be taken into consideration. Consequently it is emphasized that in practical engineering the real conditions shall be taken into account.

For geometrical conditions of usual flat rooms a maximum amount for the average temperature of the wall heating surface of $\theta_{F,m}$ = 40 °C is applicable, and the difference of the temperature between the heating surface and the room is 20K. As a result, the limit curve within the field of characteristic curves is a horizontal straight line and q_G is 160 (W/m^2), assuming that h = 8 (W/m^{2}K), based on ISO 11855-2.

If higher values $\theta_{F,m}$ > 40 °C are used, the compliance with physiological limitations shall be proved.

5.3.3 Procedure for determining the design heating medium flow rate

It is recommended to apply the procedure described in 5.1.8 accordingly taking into account the changed position of the structure shown in Figure 7 and the changes of the transfer resistances on the surfaces as follows:

1/h is the heat transfer resistance on the heating wall surface; 1/h = 0,125 (m^2·K)/W;

$R_{h,ceiling}$ is replaced by $R_{h,back}$, the heat transfer resistance on the surface of the back side of the wall;

$R_{h,back}$ = 0,13 (m^2·K)/W, in case of adjacent rooms;

$R_{h,back}$ = 0,04 (m^2·K)/W, in case of outside environments.

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5.4 Floor cooling systems

5.4.1 Design procedure

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

Step 1: Calculate the design sensible cooling load $Q_{N,s}$. The design sensible cooling load $Q_{N,s}$ does not include the adjacent heat gains. This step shall be conducted in accordance with standards for cooling load calculation, e.g. EN 15243, based on an index such as operative temperature (OT) (see ISO 11855-1).

Step 2: Determine the minimum supply air quantity needed for dehumidifying.

Step 3: Calculate latent cooling available from supply air and also calculate sensible cooling available from supply air.

Step 4: Determine remaining sensible cooling load to be satisfied by panel system. Also designate or calculate the relative humidity and dew point, because cooling system shall operate within a temperature range above the dew point, which shall be specified depending on the respective climate conditions in the country.

Step 5: Determine the area of the cooling surface A_F, excluding any area covered by immovable objects or objects fixed to the building structure.

Step 6: Establish a minimum permissible surface temperature in accordance with ISO 11855-1 in consideration of the dew point.

Step 7: Determine the design heat flux q_{des} according to Equation (1). For floor cooling 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 cooling surface A_R and on the area of the occupied cooling surface A_A complying with Equation (2).

Step 8: For the design of the floor cooling systems, determine the room used for design with the maximum design heat flux $q_{max} = q_{des}$.

Step 9: Determine the floor cooling system such as the pipe spacing and the covering type, and design cooling medium differential temperature $\Delta\theta_{H,des}$ based on the maximum design heat flux q_{max} and the minimum surface temperature $\theta_{F,min}$ from the field of characteristic curves according to ISO 11855-2 and 5.4.7 in this part of ISO 11855.

Step 10: 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 provide supplementary cooling equipment. In this case, the maximum design heat flux q_{max} for the embedded system may now occur in another room.

Step 11: Determine the backside thermal resistance of insulating layer $R_{\lambda,ins}$ and the design cooling medium flow rate m (see 5.4.6 and 5.4.8).

Step 12: Estimate the total length of heating circuit.

5.4.2 Cooling medium differential temperature

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

$$\Delta\theta_C = \frac{\theta_R - \theta_V}{\ln \dfrac{\theta_V - \theta_i}{\theta_R - \theta_i}} \tag{18}$$

In this equation, the effect of the temperature rise of the cooling medium is taken into account.

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5.4.3 Characteristic curve

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

$$q = K_H \cdot {''}\ \theta_C \quad (19)$$

5.4.4 Field of characteristic curves

In principle the specifications given in 5.1.4 for heating systems also apply accordingly.

5.4.5 Limit curves

The limit curves in the field of system characteristic curves describe the relationship between the cooling medium differential temperature $\Delta\theta_C$ and the heat flux for the limit case.

For cooling systems the dew point limits the temperature of the cooling medium on the regional value or on other design values. As a result, the limit curve within the field of characteristic curves is a vertical straight line in a distance of the cooling medium differential temperature from the ordinate, depending on the set dew point.

It can be assumed that fulfilling of the dew point limitation satisfies physiological limitations as well. This shall be proved in special cases.

5.4.6 Downwards thermal insulation

For basic information, see 5.1.6.

5.4.7 Procedure for determining the supply design temperature of cooling medium

The same procedure as for systems only for heating (5.1.7) applies, with the following additional consideration: as the cooling power may be limited by the dew point, it is important to design surface cooling systems with:

— minimum resistance of the covering;

— small temperature rise(σ approximately 3 – 5 K);

— smaller pipe spacing.

5.4.8 Procedure for determining the design cooling medium flow rate

In principle the specifications given in 5.1.8 for heating systems also apply accordingly.

5.5 Ceiling cooling systems

It is recommended to apply the descriptions for floor cooling system given in 5.4 for ceiling cooling system accordingly (in the respective wordings replace “floor cooling” by “ceiling cooling”).

5.6 Wall cooling systems

It is recommended to apply the descriptions for floor cooling system given in 5.4 for wall cooling system accordingly (in the respective wordings replace “floor cooling” by “wall cooling”).

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