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

**Part 8:
Electrical heating systems**

*Conception de l'environnement des bâtiments — Conception,
dimensionnement, installation et contrôle des systèmes intégrés de
chauffage et de refroidissement par rayonnement —*

Partie 8: Systèmes de chauffage électrique



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Foreword

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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 document 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).

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 can be applied to systems that use not only water but also other liquids 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.

The following is a summary of the ISO 11855 parts:

- 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 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 the product specific input parameters for ISO 52031.
- ISO 11855-8 (this document) presents a calculation method for electrical heating systems.

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

Part 8: Electrical heating systems

1 Scope

This document specifies procedures and conditions to enable the heat flux in electrical surface heating systems to be determined relative to the medium differential temperature for systems. The determination of thermal performance electrical surface heating 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 surface heating systems.

The surface temperature and the temperature uniformity of the heated surface, nominal heat flux density between electrical heated layer and space are given as the result.

The ISO 11855 series is applicable to water based embedded surface heating and cooling systems in residential, commercial and industrial buildings¹⁾. The methods apply to systems integrated into the wall, floor or ceiling construction without any open air gaps. It does not apply to ceiling mounted panel systems with open air gaps which are not integrated into the building structure.

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

2 Normative references

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

ISO 52000-1, *Energy performance of buildings — Overarching EPB assessment Part 1: general framework and procedure*

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 terminology 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/>

1) ISO 11855-7 can also be used for electrical heated embedded systems.

4 Symbols and subscripts

4.1 Symbols

For the purpose of this document, the symbols given in ISO 52000-1, and the following symbols (see [Table 1](#)) apply. Additional symbols are documented in ISO 11855-1.

Table 1 — Symbols and units

Symbol	Description	Unit
a	division	m
B	level area	m ²
b	width of the electrical heating element	m
l	fin length	m
m	variable of the calculation	-
n_a	operand	-
n_i	operand	-
\dot{q}	specific heat flux	W/m ²
\dot{Q}	heat flux	W
R	resistance	(m ² K)/W
U	length	m
α	heat transfer coefficient	W/(m ² K)
δ	thickness	m
$\bar{\delta}$	thickness of the spare lamella	m
δ_L	thickness of the heat conducting layer	m
δ_F	thickness of the filling layer	m
κ	part heat transfer coefficient	(m ² K)/W
λ	thermal conductivity	W/(m ² K)
ϑ	temperature	°C
φ	angle	°

4.2 Subscripts

For the purposes of this document, the symbols are in accordance with ISO 52000-1 and the special symbols shown in [Table 2](#). Additional symbols are documented in ISO 11855-1.

Table 2 — Subscripts

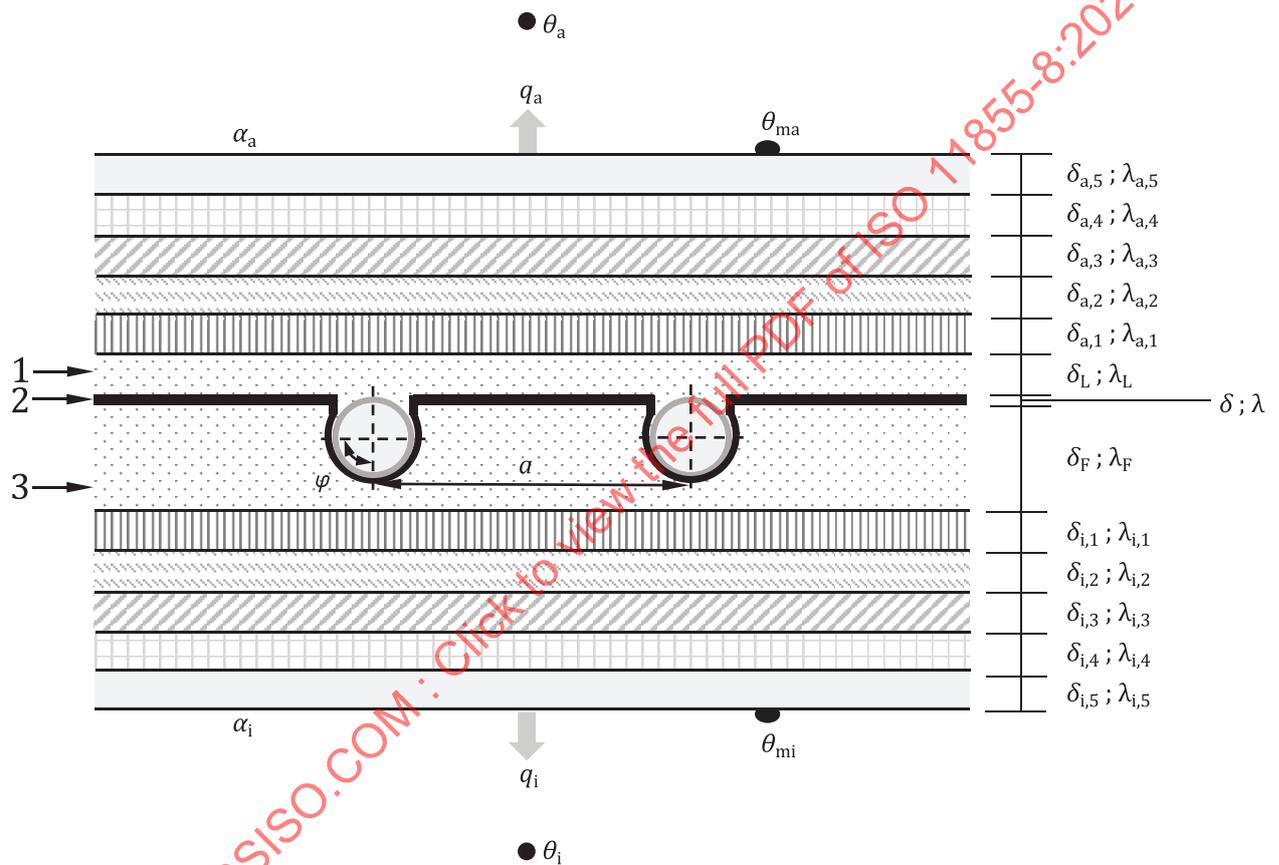
a	Room a
S	Air gap
R	in accordance to the lamella / electrical heating element
Ra	spare lamella - to room a
RBa	Coverage to room a
RBi	Coverage to room i
Ri	spare lamella - to room i
i	Room i
ges	total
1...5	layers
L	in accordance to the heat conducting layer

Table 2 (continued)

F	in accordance to the lamella
max	maximal
m	mean value

5 Calculation procedure of the heat flux

The description of the calculation method of embedded electrical heating system is based on the documented system in [Figure 1](#) and [Figure 2](#). A basic, informative flowchart of the calculation can be found in [Annex A](#).

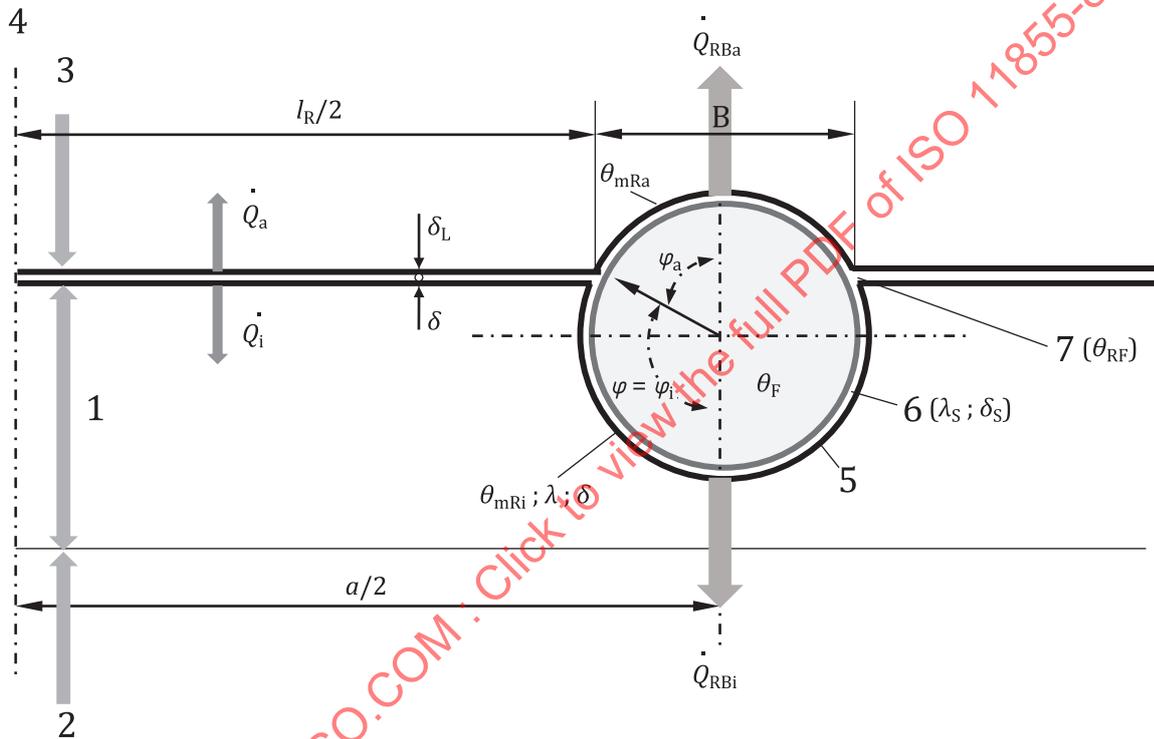


Key

- a distance between the electrical heating elements
- $\delta_{a,1..5}$ thickness of the different layers (external)
- $\delta_{i,1..5}$ thickness of the different layers (internal)
- δ_F thickness of the filling layer
- δ_L thickness of the heat conduction device
- δ thickness of the heat conduction strip
- $\lambda_{a,1..5}$ thermal conductivity (external)
- $\lambda_{i,1..5}$ thermal conductivity (internal)
- λ_F thermal conductivity of the filling layer
- λ_L thermal conductivity of the heat conduction device
- λ thermal conductivity of the heat conduction strip
- θ_a temperature (external)
- θ_i temperature (internal)
- θ_{ma} mean surface temperature (external)

- θ_{mi} mean surface temperature (internal)
- α_a heat transfer coefficient (external)
- α_i heat transfer coefficient (internal)
- φ angle
- q_i heat flux (internal room)
- q_a heat flux (external room)
- 1 heat conduction device
- 2 heat conduction strip
- 3 filling layer

Figure 1 — Principal construction of an embedded electrical heating system



Key

- a distance between the electrical heating elements
- B level area
- Q_{RBa} heat flux from the lamella - electrical heating element (external)
- Q_{RBi} heat flux from the lamella - electrical heating element (internal)
- Q_a heat flux from the lamella (external)
- Q_i heat flux from the lamella (internal)
- δ thickness
- δ_L thickness of the heat conduction device
- δ_S thickness of the air gap
- λ thermal conductivity of the heat conduction strip
- λ_S thermal conductivity air
- θ_{mRa} mean surface temperature (electrical heating element, external)
- θ_{mRi} mean surface temperature (electrical heating element, internal)
- θ_F temperature of the heating element
- θ_{RF} temperature of the foot point

φ	angle
1	filling layer
2	internal covering layer
3	external covering layer
4	plane of symmetry
5	slat on the heating element
6	air gap
7	foot point

Figure 2 — Detailed construction of an embedded electrical heating system

Based on [Figure 1](#) and [Figure 2](#), the calculation-result is the heat flux of the system to the room (a) and the heat flux to the second room (i). The calculation procedure is as follows.

The first step for the calculation is the calculation of the resistors of the internal and the external layers. The following equations have to be used:

$$R_a = \frac{\delta_{a1}}{\lambda_{a1}} + \frac{\delta_{a2}}{\lambda_{a2}} + \frac{\delta_{a3}}{\lambda_{a3}} + \frac{\delta_{a4}}{\lambda_{a4}} + \frac{\delta_{a5}}{\lambda_{a5}} = \sum_{a,n} \frac{\delta_{a,n}}{\lambda_{a,n}} \quad (1)$$

$$R_i = \frac{\delta_{i1}}{\lambda_{i1}} + \frac{\delta_{i2}}{\lambda_{i2}} + \frac{\delta_{i3}}{\lambda_{i3}} + \frac{\delta_{i4}}{\lambda_{i4}} + \frac{\delta_{i5}}{\lambda_{i5}} = \sum_{i,n} \frac{\delta_{i,n}}{\lambda_{i,n}} \quad (2)$$

By means of the resistors, the part-heat coefficients κ_a and κ_i have to be calculated. The necessary equations are:

$$\kappa_a = \left[\frac{1}{\alpha_a} + R_a \right]^{-1} \quad (3)$$

$$\kappa_i = \left[\frac{1}{\alpha_i} + R_i \right]^{-1} \quad (4)$$

For the illustration of the two lamellae (heat conducting strip/heat conducting), they shall touch each other at the base and the foot temperature ϑ_{RF} is present there. For the replacement lamella, a thermodynamic model of a flat lamella is used. In addition, it is taken into account that an air gap with the thickness of d_s can occur between the tube and the heat-conducting lamella. For the "spare lamella," the following relationship can be used:

$$l_R = a - d_s \cdot \sin(\phi) \quad (5)$$

with B :

$$B = a - l_R \quad (6)$$

Other characteristics of the replacement lamella are the thickness and thermal conductivity associated with the subsequent formulae.

$$\bar{\delta} = \delta_L + \delta \quad (7)$$

$$\lambda = \frac{\lambda_L \cdot \delta_L + \lambda \cdot \delta}{\delta_L + \delta} \quad (8)$$

The lower lamella often rests on a filling layer (insulating material). The outer and inner cover layer connect directly to the replacement lamella or to the filling layer. For the spare lamella and for the lamella around the tube, a separate calculation is made in the first step. The mean temperature of the lamella is determined by [Formula 9](#).

$$\theta_m = (\theta_{RF} - \theta_B) \cdot \frac{\tanh\left[m \cdot \frac{l_R}{2}\right]}{m \cdot \frac{l_R}{2}} + \theta_B \quad (9)$$

with:

$$\theta_B = \frac{(\kappa_a \cdot \theta_a + \kappa_i \cdot \theta_i)}{\kappa_a + \kappa_i} \quad (10)$$

$$m = \sqrt{\frac{\kappa_a + \kappa_i}{\delta \cdot \lambda}} \quad (11)$$

The calculation of the heat flux to the space (a) and (i) is carried out according to the following calculation:

$$\dot{Q}_a = \kappa_a \cdot (\theta_m - \theta_a) \cdot b \cdot \frac{l_R}{2} \quad (12)$$

$$\dot{Q}_i = \kappa_i \cdot (\theta_m - \theta_i) \cdot b \cdot \frac{l_R}{2} \quad (13)$$

For the calculation around the electrical heating element the following formula can be used:

$$\dot{Q}_{Ra} = -\delta_L \cdot \lambda_L \cdot n_a \cdot (\theta_{RF} - \theta_{Ca}) \cdot \tanh\left[n_a \cdot d_S \cdot \frac{\varphi_a}{2}\right] \quad (14)$$

$$\dot{Q}_{Ri} = -\delta_L \cdot \lambda_L \cdot n_i \cdot (\theta_{RF} - \theta_{Ci}) \cdot \tanh\left[n_i \cdot d_S \cdot \frac{\varphi_i}{2}\right] \quad (15)$$

The quantities n_a , ϑ_{Ca} , n_i , θ_{Ci} , necessary for the calculation of the heat flux are determined with the [Formulae 16](#) to [20](#).

$$n_a = \sqrt{\frac{\kappa_a + \kappa_R}{\lambda_L \cdot \delta_L}} \quad (16)$$

$$n_i = \sqrt{\frac{\kappa_i + \kappa_R}{\lambda_L \cdot \delta_L}} \quad (17)$$

$$\theta_{Ca} = \frac{\kappa_a \cdot \theta_a + \kappa_R \cdot \theta_F}{\kappa_i + \kappa_R} \quad (18)$$

$$\theta_{Ci} = \frac{\kappa_i \cdot \theta_i + \kappa_R \cdot \theta_F}{\kappa_i + \kappa_R} \quad (19)$$