BS EN ISO 11855-4:2021+A1:2023



BSI Standards Publication

Building environment design — Embedded radiant heating and cooling systems

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

Documents
Document Sharing Hub

Full document details: BS EN ISO 11855-4:2021+A1:2023

National foreword

This British Standard is the UK implementation of EN ISO 11855-4:2021+A1:2023. It is identical to ISO 11855-4:2021, incorporating amendment 1:2023. It supersedes BS EN ISO 11855-4:2021, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO text carry the number of the ISO amendment. For example, text altered by ISO amendment 1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee RHE/2, Ventilation for buildings, heating and hot water services.

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

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2023
Published by BSI Standards Limited 2023

ISBN 978 0 539 19578 1

ICS 91.040.01; 91.140.10

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2021.

Amendments/corrigenda issued since publication

Date	Text affected
30 November 2023	Implementation of ISO amendment 1:2023 with CEN endorsement A1:2023

Documents
Document Sharing Hub

Full document details: BS EN ISO 11855-4:2021+A1:2023

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 11855-4:2021+A1

October 2023

ICS 91.040.01

Supersedes EN ISO 11855-4:2015

English Version

Building environment design - Embedded radiant heating and cooling systems - Part 4: Dimensioning and calculation of the dynamic heating and cooling capacity of Thermo Active Building Systems (TABS) (ISO 11855-4:2021)

Conception de l'environnement des bâtiments - Systèmes intégrés de chauffage et de refroidissement par rayonnement - Partie 4: Dimensionnement et calculs relatifs au chauffage adiabatique et à la puissance frigorifique pour systèmes d'éléments de construction thermoactifs (TABS) (ISO 11855-4:2021)

Umweltgerechte Gebäudeplanung - Flächenintegrierte Strahlheizungs- und -kühlsysteme - Teil 4: Auslegung und Berechnung der dynamischen Wärme- und Kühlleistung für thermoaktive Bauteilsysteme (TABS) (ISO 11855-4:2021)

This European Standard was approved by CEN on 29 July 2021.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

© 2021 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. EN ISO 11855-4:2021 E

Documents
Document Sharing Hub

Full document details: BS EN ISO 11855-4:2021+A1:2023

European foreword

This document (EN ISO 11855-4:2021) has been prepared by Technical Committee ISO/TC 205 "Building environment design" in collaboration with 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 March 2022, and conflicting national standards shall be withdrawn at the latest by March 2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 11855-4:2015.

Any feedback and questions on this document should be directed to the users’ national standards body/national committee. A complete listing of these bodies can be found on the CEN websites.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 11855-4:2021 has been approved by CEN as EN ISO 11855-4:2021 without any modification.

European foreword to Amendment 1

This document (EN ISO 11855-4:2021/A1:2023) has been prepared by Technical Committee ISO/TC 205 "Building environment design" in collaboration with Technical Committee CEN/TC 228 “Heating systems and water based cooling systems in buildings” the secretariat of which is held by DIN.

This Amendment to the European Standard EN ISO 11855-4:2021 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2024, and conflicting national standards shall be withdrawn at the latest by April 2024.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users’ national standards body/national committee. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Endorsement notice

The text of ISO 11855-4:2021/Amd 1:2023 has been approved by CEN as EN ISO 11855-4:2021/A1:2023 without any modification.

Documents
Document Sharing Hub

Full document details: BS EN ISO 11855-4:2021+A1:2023

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Symbols **1**
5 The concept of thermally active building surfaces (TABS) **4**
6 Calculation methods **10**
6.1 General 10
6.2 Rough sizing method 13
6.3 Simplified sizing by diagrams 13
6.4 Simplified model based on FDM 19
6.4.1 Cooling system 20
6.4.2 Hydraulic circuit and slab 20
6.4.3 Room 22
6.4.4 Limits of the method 24
6.5 Dynamic building simulation programs 25
7 Effects of acoustic ceiling units on the cooling performance of TABS **25**
8 Input for computer simulations of energy performance **25**
Annex A (informative) **Simplified diagrams** **27**
Annex B (normative) **Calculation method** **33**
Annex C (informative) **Tutorial guide for assessing the model** **44**
Annex D (informative) **Computer program** **47**
Bibliography **58**

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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 11855-4:2012), which has been technically revised.

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

— editorial corrections;

— picture redraws;

— updated Bibliography;

— improved wording.

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.

© ISO 2021 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

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*

[A1] 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 (this document) provides a dimensioning and calculation method to design Thermo Active Building Systems (TABS) – Type V 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. [/A1]

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

Documents
Document Sharing Hub

Full document details: BS EN ISO 11855-4:2021+A1:2023

Building environment design — Embedded radiant heating and cooling systems —

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

1 Scope

〈A1〉 This document allows the calculation of peak cooling capacity of Thermo Active Building Systems (TABS) – Type V according to ISO 11855-1, based on heat gains, such as solar gains, internal heat gains, and ventilation, and the calculation of the cooling power demand on the water side, to be used to size the cooling system, as regards, e.g. the chiller size, fluid flow rate. 〈A1〉

This document defines a detailed method aimed at the calculation of heating and cooling capacity in non-steady state conditions.

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: Definitions, symbols, and comfort criteria*

ISO 11855-2, *Building environment design — 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.

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/cooling surface area
A_W	m^2	Total area of internal vertical walls (i.e. vertical walls, external façades excluded)
C	$J/(m^2 \cdot K)$	Specific thermal capacity of the thermal node under consideration

Documents
Document Sharing Hub

© ISO 2021 – All rights reserved

Full document details: BS EN ISO 11855-4:2021+A1:2023

Table 1 *(continued)*

Symbol	Unit	Quantity
C_W	J/(m²·K)	Average specific thermal capacity of the internal walls
c_j	J/(kg·K)	Specific heat of the material constituting the *j*-th layer of the slab
c_{Wa}	J/(kg·K)	Specific heat of water
d_a	m	External diameter of the pipe
E_{Day}	kWh/m²	Specific daily energy gains
f_{rm}^h	-	Running mode (1 when the system is running; 0 when the system is switched off) in the *h*-th hour
f_s	-	Design safety factor
$F_{v\ F\text{-}C}$	-	View factor between the floor and the ceiling
$F_{v\ F\text{-}EW}$	-	View factor between the floor and the external walls
$F_{v\ F\text{-}W}$	-	View factor between the floor and the internal walls
$h_{A\text{-}C}$	W/(m²·K)	Convective heat transfer coefficient between the air and the ceiling
$h_{A\text{-}F}$	W/(m²·K)	Convective heat transfer coefficient between the air and the floor
$h_{A\text{-}W}$	W/(m²·K)	Convective heat transfer coefficient between the air and the internal walls
$h_{F\text{-}C}$	W/(m²·K)	Radiant heat transfer coefficient between the floor and the ceiling
$h_{F\text{-}W}$	W/(m²·K)	Radiant heat transfer coefficient between the floor and the internal walls
H_A	W/K	Heat transfer coefficient between the thermal node under consideration and the air thermal node ("A")
H_C	W/K	Heat transfer coefficient between the thermal node under consideration and the ceiling surface thermal node ("C")
H_{Cct}	W/K	Heat transfer coefficient between the thermal node under consideration and the circuit
H_{CondDn}	W/K	Heat transfer coefficient between the thermal node under consideration and the next one
H_{CondUp}	W/K	Heat transfer coefficient between the thermal node under consideration and the previous one
H_{Conv}	-	Fraction of internal convective heat gains acting on the thermal node under consideration
H_F	W/K	Heat transfer coefficient between the thermal node under consideration and the floor surface thermal node ("F")
H_I	W/K	Coefficient connected to the inertia contribution at the thermal node under consideration
H_{IWS}	W/K	Heat transfer coefficient between the thermal node under consideration and the internal wall surface thermal node ("IWS")
H_{Rad}	-	Fraction of total radiant heat gains impinging on the thermal node under consideration
h_t	W/(m²·K)	Total heat transfer coefficient (convection + radiation) between surface and space
J	-	Number of layers constituting the slab as a whole
J_1	-	Number of layers constituting the upper part of the slab
J_2	-	Number of layers constituting the lower part of the slab
L_R	m	Length of installed pipes
$\dot{m}_{H,sp}$	kg/(m²·s)	Specific water flow in the circuit, calculated on the area covered by the circuit
m_j	-	Number of partitions of the *j*-th layer of the slab
n	-	Actual number of iteration in iterative calculations
n_h	h	Number of operation hours of the circuit
n_{Max}	-	Maximum number of iterations allowed in iterative calculations

© ISO 2021 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

Table 1 *(continued)*

Symbol	Unit	Quantity
$P_{\mathrm{Cct}}^{\mathrm{Max},h}$	W	Maximum cooling power reserved to the circuit under consideration in the *h*-th hour
$P_{\mathrm{Cct,Spec}}^{\mathrm{Max}}$	W/m^2	Maximum specific cooling power (per floor square metre)
q_{i}	W/m^2	Inward specific heat flux
q_{u}	W/m^2	Outward specific heat flux
Q_{C}^{h}	W	Heat flux impinging on the ceiling surface ("C") in the *h*-th hour
Q_{Cct}^{h}	W	Heat flux extracted by the circuit in the *h*-th hour
Q_{Conv}^{h}	W	Total convective heat gains in the *h*-th hour
Q_{F}^{h}	W	Heat flux impinging on the floor surface ("F") in the *h*-th hour
Q_{IntConv}^{h}	W	Internal convective heat gains in the *h*-th hour
Q_{IntRad}^{h}	W	Internal radiant heat gains in the *h*-th hour
Q_{IWS}^{h}	W	Heat flux impinging on the internal wall surface ("IWS") in the *h*-th hour
Q_{PrimAir}^{h}	W	Primary air convective heat gains in the *h*-th hour
Q_{Rad}^{h}	W	Total radiant heat gains in the *h*-th hour
Q_{Sun}^{h}	W	Solar heat gains in the room in the *h*-th hour
Q_{Transm}^{h}	W	Transmission heat gains in the *h*-th hour
Q_{W}	W/m^2	Average specific cooling power
R	(m^2·K)/W	Generic thermal resistance
$R_{\mathrm{Add\ C}}$	(m^2·K)/W	Additional thermal resistance covering the lower side of the slab
$R_{\mathrm{Add\ F}}$	(m^2·K)/W	Additional thermal resistance covering the upper side of the slab
R_{int}	(m^2·K)/W	Internal thermal resistance of the slab conductive region
$R_{\mathrm{L},p}$	(m^2·K)/W	Conduction thermal resistance connecting the *p*-th thermal node with the boundary of the (p+1)-th thermal node
R_{r}	(m^2·K)/W	Pipe thickness thermal resistance
R_{t}	(m^2·K)/W	Circuit total thermal resistance
$R_{\mathrm{U},p}$	(m^2·K)/W	Conduction thermal resistance connecting the *p*-th thermal node with the boundary of the (p-1)-th thermal node
R_{W}	(m^2·K)/W	Wall surface thermal resistance
$R_{\mathrm{W}a}$	(m^2·K)/W	Water flow thermal resistance
R_{x}	(m^2·K)/W	Pipe level thermal resistance
R_{z}	(m^2·K)/W	Convection thermal resistance at the pipe inner side
s_{r}	m	Pipe wall thickness
s_1	M	Thickness of the upper part of the slab
s_2	m	Thickness of the lower part of the slab
W	m	Pipe spacing
δ_j	m	Thickness of the *j*-th layer of the slab
$\Delta\theta$	K	Generic temperature difference

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

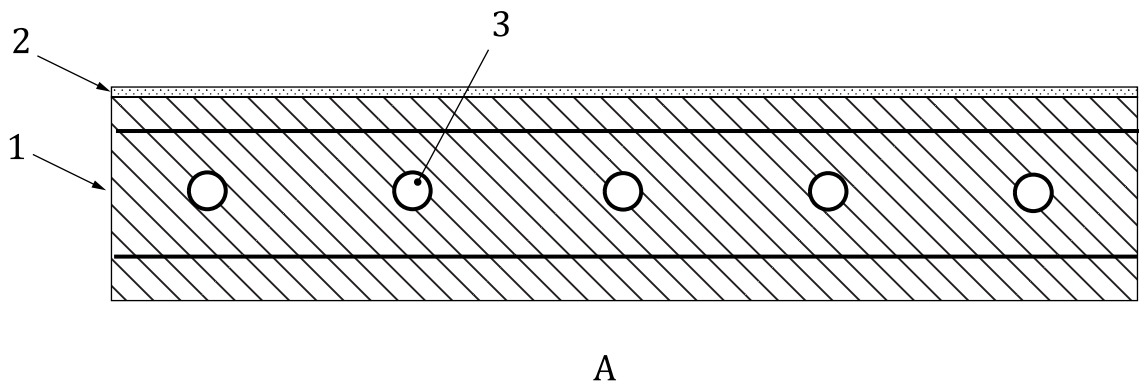
Table 1 *(continued)*

Symbol	Unit	Quantity
$\Delta\theta_{Comfort}^{Max}$	K	Maximum operative temperature drift allowed for comfort conditions
Δt	s	Calculation time step
θ_A^h	°C	Temperature of the air thermal node ("A") in the *h*-th hour
θ_C^h	°C	Temperature of the ceiling surface thermal node ("C") in the *h*-th hour
$\Delta\theta_{Comf}^{Max}$	°C	Maximum operative temperature allowed for comfort conditions
$\theta_{Comf,Ref}$	°C	Maximum operative temperature allowed for comfort conditions in the reference case
θ_F^h	°C	Temperature of the floor surface thermal node ("F") in the *h*-th hour
θ_{IW}^h	°C	Temperature of the core of the internal walls thermal node ("IW") in the *h*-th hour
θ_{IWS}^h	°C	Temperature of the internal wall surface thermal node ("IWS") in the *h*-th hour
θ_{MR}^h	°C	Room mean radiant temperature in the *h*-th hour
θ_{Op}^h	°C	Room operative temperature in the *h*-th hour
θ_p^h	°C	Temperature of the *p*-th thermal node in the *h*-th hour
θ_{PL}^h	°C	Temperature of the pipe level thermal node ("PL") in the *h*-th hour
θ_{Slab}^{Av}	°C	Daily average temperature of the conductive region of the slab
$\theta_{Wa,In}^h$	°C	Water inlet actual temperature in the *h*-th hour
$\theta_{Wa,In}^{Setp,h}$	°C	Water inlet set-point temperature in the *h*-th hour
$\theta_{Wa,In,Ref}^{Setp}$	°C	Water inlet set-point temperature in the reference case
$\theta_{Wa,Out}^h$	°C	Water outlet temperature in the *h*-th hour
λ_b	W/(m·K)	Thermal conductivity of the material of the pipe embedded layer
λ_j	W/(m·K)	Thermal conductivity of the material constituting the *j*-th layer of the slab
λ_r	W/(m·K)	Thermal conductivity of the material constituting the pipe
ξ	K	Actual tolerance in iterative calculations
ξ_{Max}	K	Maximum tolerance allowed in iterative calculations
ρ_j	kg/m^3	Density of the material constituting the *j*-th layer of the slab
ω	various	Slope of correlation curves

5 The concept of thermally active building surfaces (TABS)

A thermally active building surface (TABS) is an embedded water-based surface heating and cooling system, where the pipe is embedded in the central concrete core of a building construction (see Figure 1).

© ISO 2021 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



Key

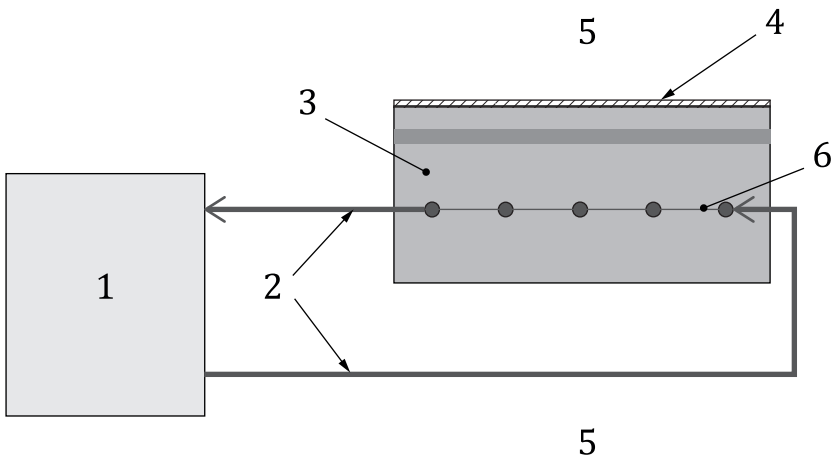
1 structural layer
2 surface layer
3 pipes or electric cables
A room

Figure 1 — Example of position of pipes in TABS

The building constructions embedding the pipe are usually the horizontal ones. As a consequence, in the following sections, floors and ceilings are usually referred to as active surfaces. Looking at a typical structure of a thermally active building surfaces (TABS), heat is removed by a cooling system (for instance, a chiller), connected to pipes embedded in the slab. The system can be divided into the elements shown in Figure 2.

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



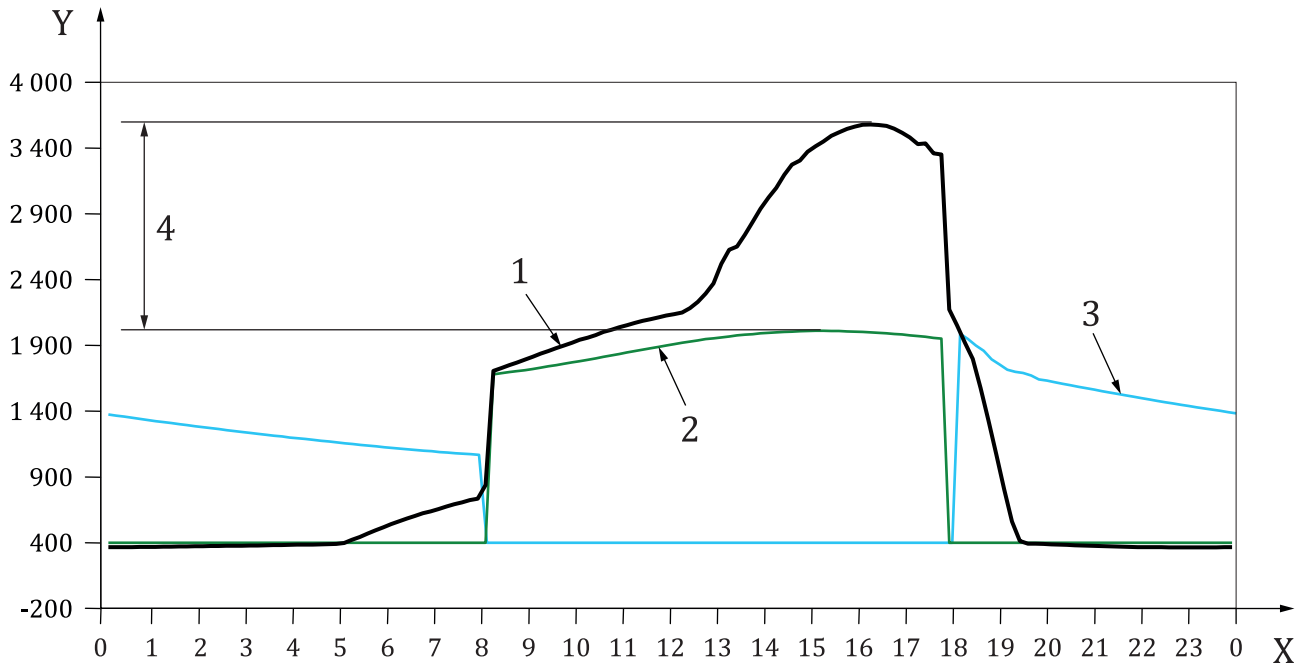
Key

1 heating and cooling equipment
2 hydraulic circuit
3 slab including core layer with pipes and reinforcement
4 possible additional resistances (floor covering or suspended ceiling)
5 room below and room above
6 pipe level

Figure 2 — Simple scheme of a TABS

Thermally active surfaces exploit the high thermal inertia of the slab in order to perform the peak-shaving. The peak-shaving consists in reducing the peak in the required cooling power (see Figure 3), so that it is possible to cool the structures of the building during a period in which the occupants are absent (during night time, in office premises). This way the energy consumption can be reduced and a lower night time electricity rate can be used. At the same time a reduction in the size of heating and cooling system components (including the chiller) is possible.

© ISO 2021 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



Key

X time, h
Y cooling power, W
1 heat gain
2 cooling power needed for conditioning the ventilation air
3 cooling power needed on the water side
4 reduction of the required peak power

Figure 3 — Example of peak-shaving effect

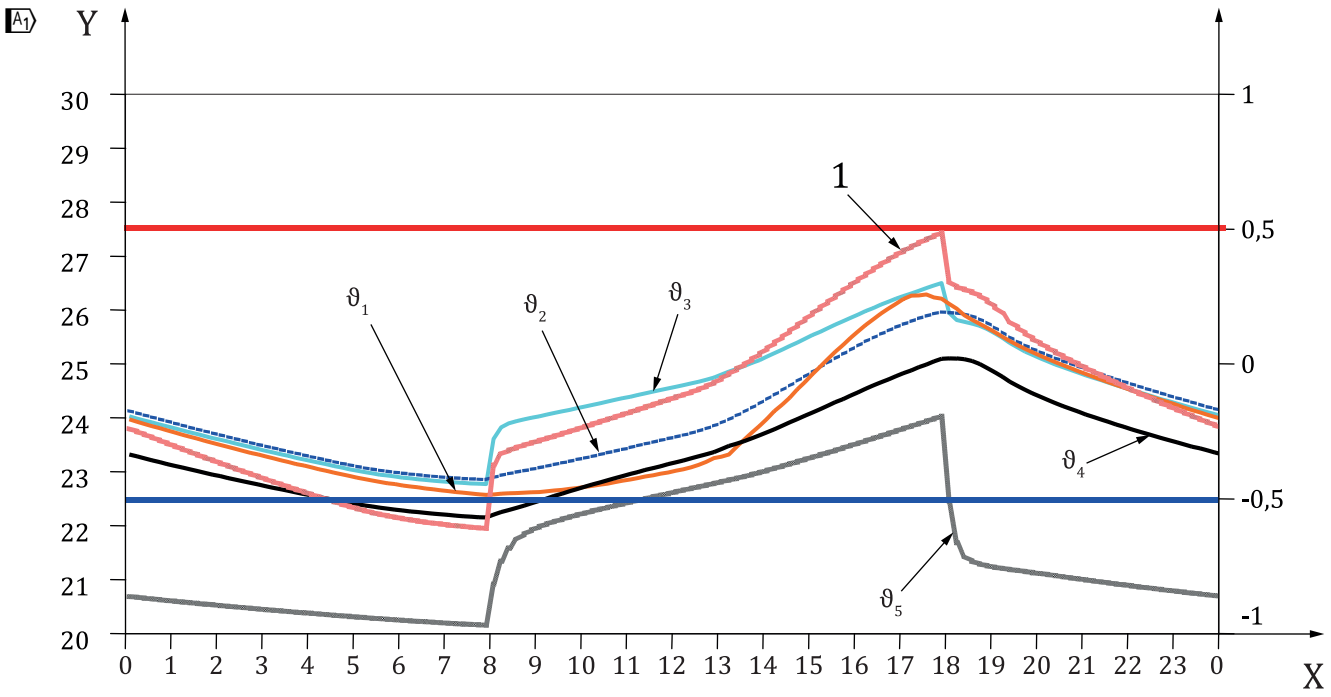
TABS can be used both with natural and mechanical ventilation (depending on weather conditions). Mechanical ventilation with dehumidifying can be required depending on external climate and indoor humidity production. In the example in Figure 3, the required peak cooling power needed for dehumidifying the air during day time is sufficient to cool the slab during night time.

As regards the design of TABS, the planner needs to know if the capacity at a given water temperature is sufficient to keep the room temperature within a given comfort range. Moreover, the planner needs also to know the heat flux on the water side to be able to dimension the heat distribution system and the chiller and boiler. This document provides methods for both purposes.

When using TABS, the indoor temperature changes moderately during the day and the aim of a good TABS design is to maintain internal conditions within the range of comfort, i.e. $-0,5 < PMV < 0,5$, during the day, according to ISO 7730 (see Figure 4).

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



Key

X	time, h
Y	temperature, °C
1	predicted mean vote
θ_1	floor temperature
θ_2	mean radiant temperature
θ_3	air temperature
θ_4	ceiling temperature
θ_5	water return temperature

Figure 4 — Example of temperature profiles and PMV values versus time

Some detailed building system calculation models have been developed to determine the heat exchanges under unsteady state conditions in a single room, the thermal and hygrometric balance of the room air, prediction of comfort conditions, check of condensation on surfaces, availability of control strategies and calculation of the incoming solar radiation. The use of such detailed calculation models is, however, limited due to the high amount of time needed for the simulations. The development of a more user-friendly tool is required. Such a tool is provided in this document and allows the simulation of TABS.

The diagrams in Figure 5 show an example of the relation between internal heat gains, water supply temperature, heat transfer on the room side, hours of operation and heat transfer on the water side. The diagrams refer to a concrete slab with raised floor (R = 0,45 (m^2·K)/W) and an allowed room temperature range of 21 °C to 26 °C.

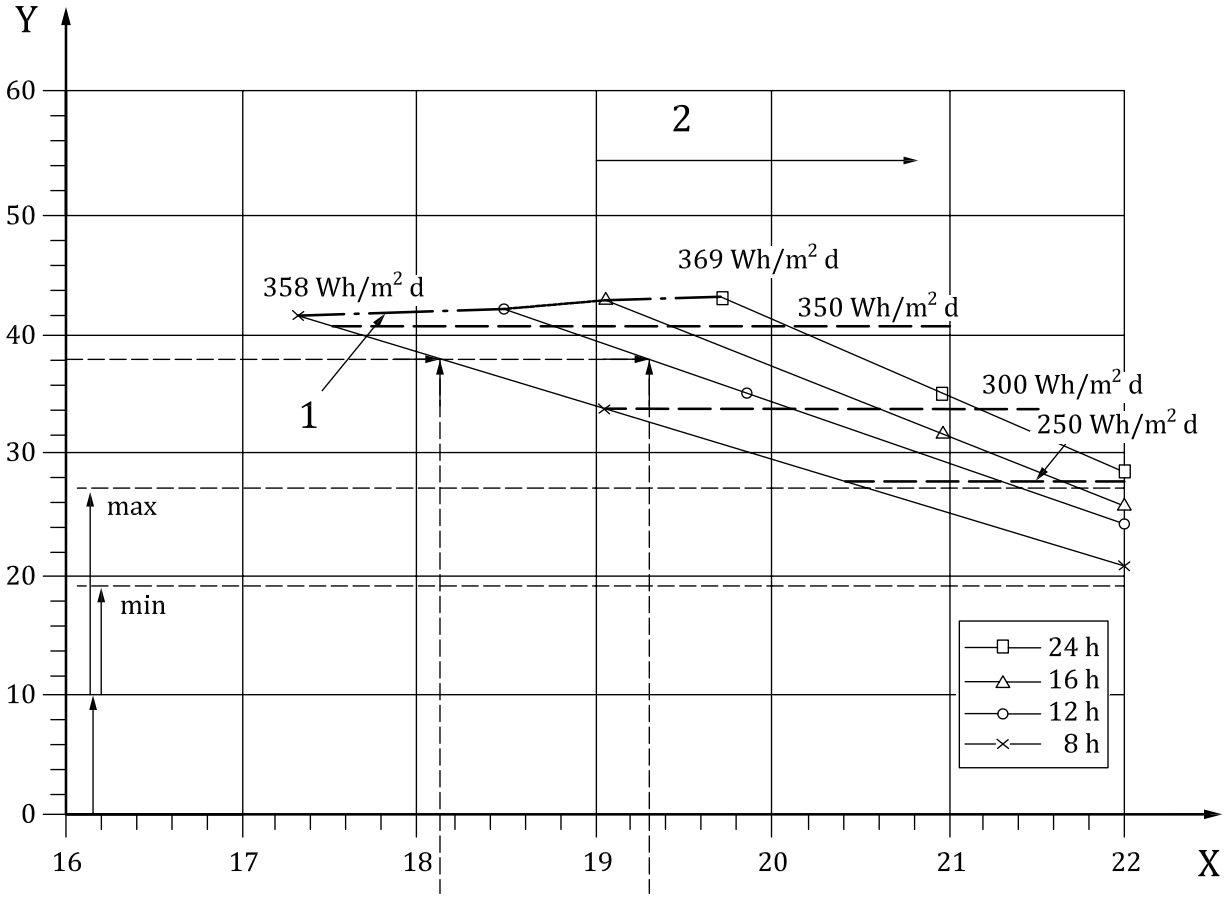
The upper diagram shows on the Y-axis the maximum permissible total heat gain in space (internal heat gains plus solar gains) [W/m^2], and on the X-axis the required water supply temperature. The lines in the diagram correspond to different operation periods (8 h, 12 h, 16 h, and 24 h) and different maximum amounts of energy supplied per day [Wh/(m^2·d)].

The lower diagram shows the cooling power [W/m^2] required on the water side (to dimension the chiller) for TABS as a function of supply water temperature and operation time. Further, the amount of energy rejected per day is indicated [Wh/(m^2·d)].

The example shows that, for a maximum internal heat gain of 38 W/m^2 and 8 h operation, a supply water temperature of 18,2 °C is required. If, instead, the system is in operation for 12 h, a supply

© ISO 2021 – All rights reserved
Documents Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

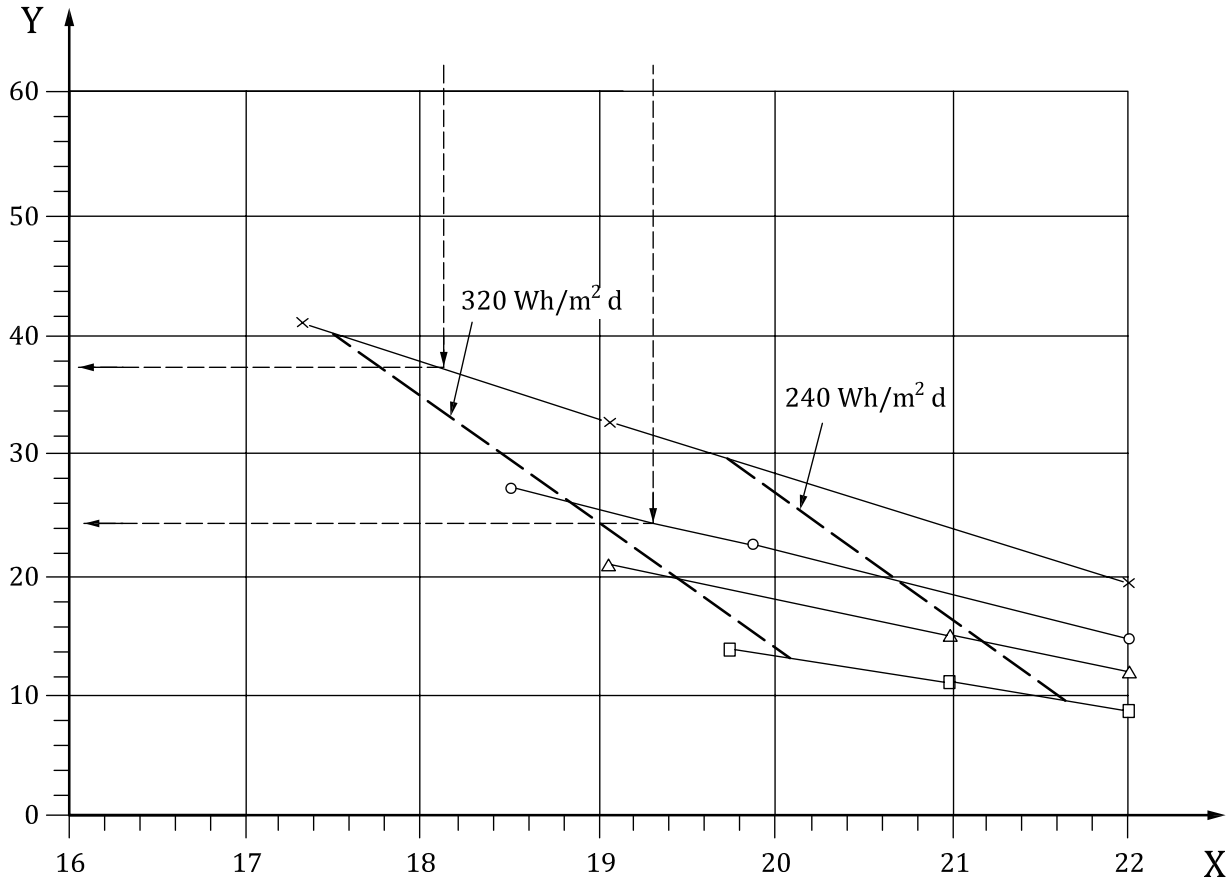
water temperature of 19,3 °C is required. In total, the amount of energy rejected from the room is approximately 335 Wh/m^2 per day. In the same conditions, the required cooling power on the water side is 37 W/m^2 (for 8 h operation) and 25 W/m^2 (for 12 h operation) respectively. Thus, by 12 h operation, the chiller can be much smaller.



a)

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



b)

Key

X (upper diagram)	supply temperature tabs, °C
Y (upper diagram)	maximum total heat gain in space (W/m^2, floor area)
Y (lower diagram)	mean cooling power tabs (W/m^2, floor area)
1	maximurn temperature increase (21 °C - 26 °C)
2	self-regulating effect of slab

Figure 5 — Working principle of TABS

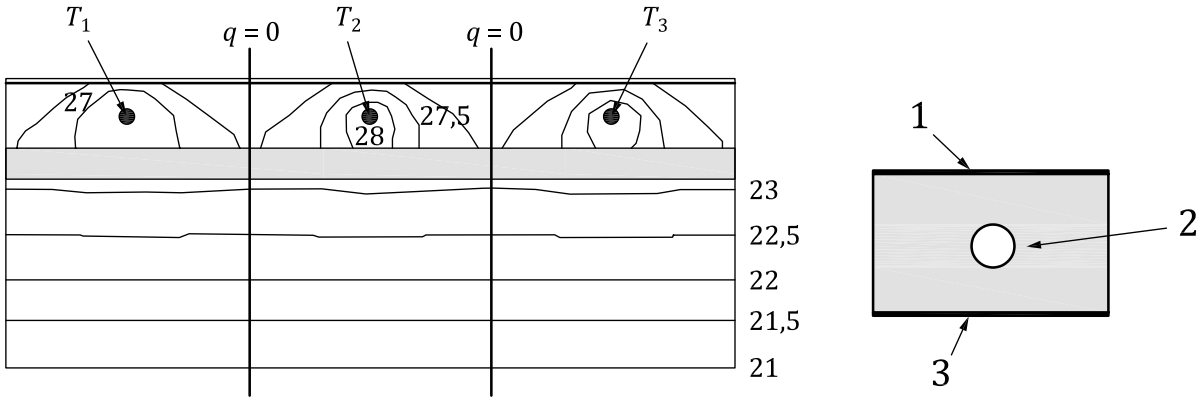
6 Calculation methods

6.1 General

TABS are systems with high thermal inertia. Therefore, for sizing chillers coupled with them, dynamic simulations shall be carried out. In principle, the solution of heat transfer inside structures with embedded pipes shall deal with 2-D calculations (see Figure 6). The calculation time required to consider the 2-D thermal field and the overall balance with the rest of the room is usually too high. Therefore, mathematical models in literature are usually based on a link between the pipe surface and the upper and lower surfaces (i.e. floor and ceiling).

One possibility to model radiant systems is to apply response factors to the pipe surface, upper surface and lower surface of the slab (see Figure 7). This way, the conduction heat transfer is defined via nine response factor series, that can be reduced to six response factor series, because of reciprocity rules.

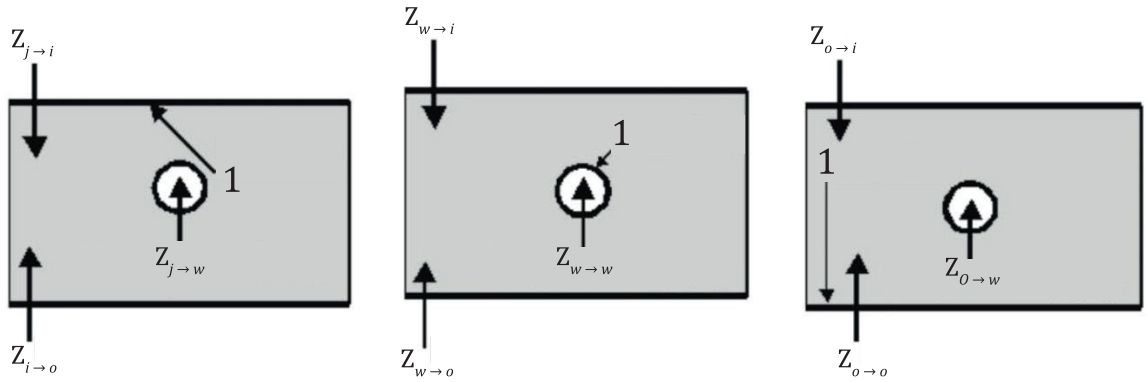
© ISO 2021 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



Key

1 upper surface
2 pipe surface
3 lower surface

Figure 6 — Heat transfer through structures containing pipes



Key

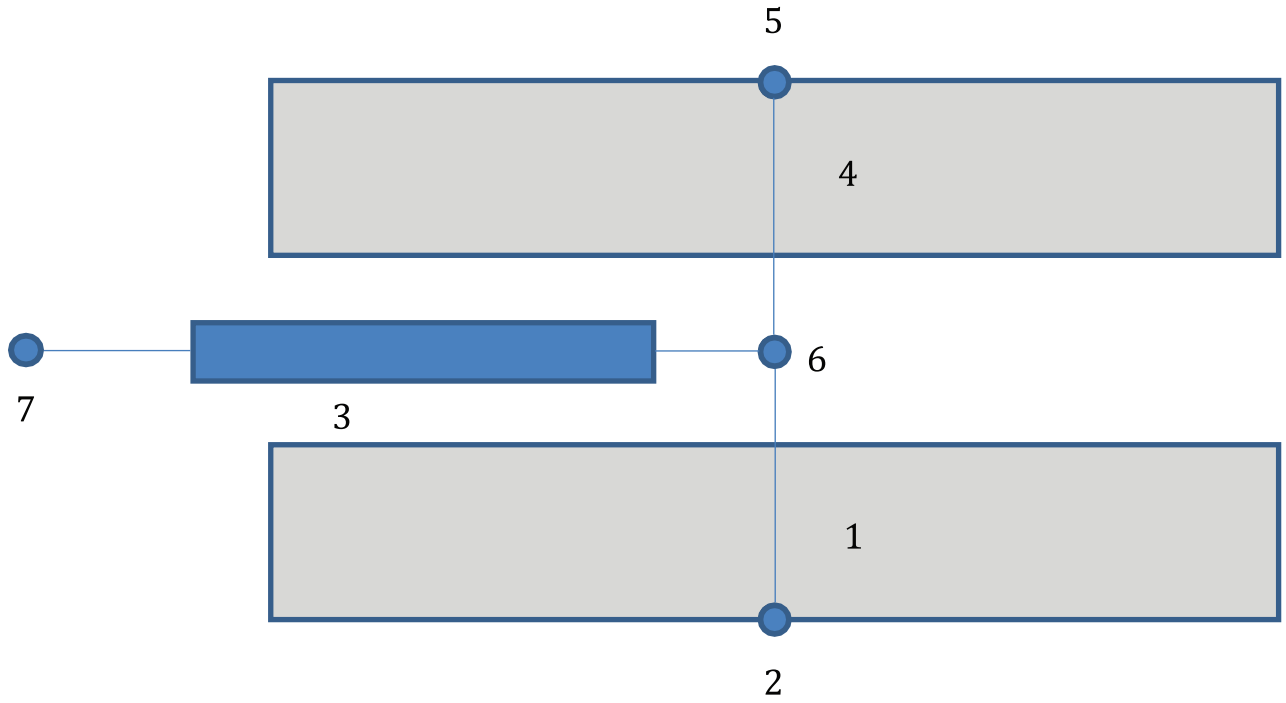
1 impulse

Figure 7 — Transfer functions for building elements containing pipes

Another possibility is to consider a resistance between the external pipe surface and an equivalent core temperature at pipe level, which represents the average temperature along the axial plane of the pipes (see Figure 8). From the core level to upward and downward levels, a 1-D resistance-capacity network or 1-D response factor series (or transfer function) can be applied.

© ISO 2021 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023



Key

1	lower part of the slab
2	lower surface temperature (ceiling)
3	circuit total thermal resistance
4	upper part of the slab
5	upper surface temperature (floor)
6	mean temperature at the pipe level
7	water supply temperature

Figure 8 — Simplified model for the conductive heat transfer in a structure containing pipes

In this document, the following calculation methods are presented.

— Rough-sizing method, based on a standard calculation of the cooling load (error: 20 % to 30 %). To be used starting from the knowledge of the daily heat gains in the room (see 6.2).

— Simplified method using diagrams for sizing, based on the knowledge of the total energy to be extracted daily to ensure comfort conditions (error: 15 % to 20 %). For details, see 6.3.

— Simplified model based on finite difference method (FDM) (error: 10 % to 15 %). It consists in detailed dynamic simulations predicting the heat transfers in the slab and even in the room via FDM. Based on the knowledge of the values of the variable cooling loads of the room during each hour of the day. For further details, see 6.4. Annex A describes simplified diagrams based on the simplified calculation method reported in 6.4,

— Detailed simulation models (error: 6 % to 10 %). It implies the overall dynamic simulation model for the radiant system and the room via detailed building-system simulation software (see 6.5).

© ISO 2021 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023

6.2 Rough sizing method

The cooling system shall be sized via the following Formula (1):

$$P_{\mathrm{Cct,Spec}}^{\mathrm{Max}} = \frac{E_{\mathrm{Day}}}{n_{\mathrm{h}}} \cdot 1\ 000 \cdot f_{\mathrm{s}} \tag{1}$$

where

$P_{\mathrm{Cct,Spec}}^{\mathrm{Max}}$ is the maximum specific cooling power (per floor square metre) in W/m^2;

E_{Day} is the specific daily energy gains in kWh/m^2;

n_{h} is the number of operation hours of the circuit in h;

f_{s} is the safe design factor (greater than one, usually 1,15) in -.

For this purpose, E_{Day} shall be calculated in the following way:

— the hourly values of heat gains are calculated for the room under the design conditions and occupancy schedules, via an energy simulation tool or a proper method for the calculation of heat gains;

— E_{Day} is the sum of the 24 values of heat gains.

The heat gains calculation shall be carried out using an operative temperature 0,5 °C lower than the average operative temperature during occupancy hours, for the sake of safe design. As a consequence, if the room operative temperature drift during occupancy hours is 21,0 °C to 26,0 °C, then the room average operative temperature during occupancy hours is 23,5 °C, and the reference room operative temperature for the calculation of heat gains is 23,0 °C.

6.3 Simplified sizing by diagrams

In this case, the calculation of the heat gains shall be carried out by means of the value of the total cooling energy to be provided during the day in order to ensure comfort conditions at the average operative temperature (for instance, 23,0 °C). This method is based on the assumption that the entire thermally conductive part of the slab is maintained at an almost constant temperature during the whole day, due to its own thermal inertia and the thermal resistance dividing it from the rooms over and below. This average temperature of the slab is calculated by the method itself and is used to calculate the water supply temperature depending on the running time of the circuit.

The following magnitudes are involved in this method.

— E_{Day} : specific daily energy gains in the room during the design day. It consists of the sum of heat gains values acting during the whole design day, divided by the floor area, in kWh/m^2.

— $\theta_{\mathrm{Comf}}^{\mathrm{Max}}$: maximum operative room temperature allowed for comfort conditions, in °C.

— Orientation of the room: used to determine when the peak load in heat gains happens [east (morning), south (noon) or west (afternoon)].

— Number of active surfaces: distinguishes whether the slab works transferring heat both through the floor side and through the ceiling side or just through the ceiling side (see Figures 9, 10 and 11).

— n_{h} : number of operation hours of the circuit in h.

— R_{Int} : internal thermal resistance of the slab conductive region in (m^2·K)/W. It is the average thermal resistance that connects the conductive parts of the slab placed near the pipe level to the pipe level itself [see Formula (4)].

© ISO 2021 – All rights reserved

AVA Documents Document Sharing Hub
Full document details: BS EN ISO 11855-4:2021+A1:2023