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## 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)

*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)*

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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](http://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](http://www.iso.org/patents)).

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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](http://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](http://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 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) for energy saving purposes, since radiant heating and cooling systems can reduce energy consumption and heat source size by using renewable energy. ISO 11855-5 addresses the installation process for the system to operate as intended. ISO 11855-6 shows a proper control method of the radiant heating and cooling systems to ensure the maximum performance which was intended in the design stage when the system is actually being operated in a building. ISO 11855-7 presents a calculation method for input parameters to ISO 52031.

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# Building environment design — Embedded radiant heating and cooling systems —

## Part 4:

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

## 1 Scope

This document allows the calculation of peak cooling capacity of Thermo Active Building Systems (TABS), 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 the chiller size, fluid flow rate, etc.

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 and abbreviated terms

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

**Table 1 — Symbols and abbreviated terms**

Symbol	Unit	Quantity
$A_F$	m <sup>2</sup>	Area of the heating/cooling surface area
$A_W$	m <sup>2</sup>	Total area of internal vertical walls (i.e. vertical walls, external façades excluded)
$C$	J/(m <sup>2</sup> ·K)	Specific thermal capacity of the thermal node under consideration

Table 1 (continued)

Symbol	Unit	Quantity
$C_W$	J/(m <sup>2</sup> ·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/m <sup>2</sup>	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
$F_{v F-C}$	-	View factor between the floor and the ceiling
$F_{v F-EW}$	-	View factor between the floor and the external walls
$F_{v F-W}$	-	View factor between the floor and the internal walls
$h_{A-C}$	W/(m <sup>2</sup> ·K)	Convective heat transfer coefficient between the air and the ceiling
$h_{A-F}$	W/(m <sup>2</sup> ·K)	Convective heat transfer coefficient between the air and the floor
$h_{A-W}$	W/(m <sup>2</sup> ·K)	Convective heat transfer coefficient between the air and the internal walls
$h_{F-C}$	W/(m <sup>2</sup> ·K)	Radiant heat transfer coefficient between the floor and the ceiling
$h_{F-W}$	W/(m <sup>2</sup> ·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/(m <sup>2</sup> ·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/(m <sup>2</sup> ·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



Table 1 (continued)

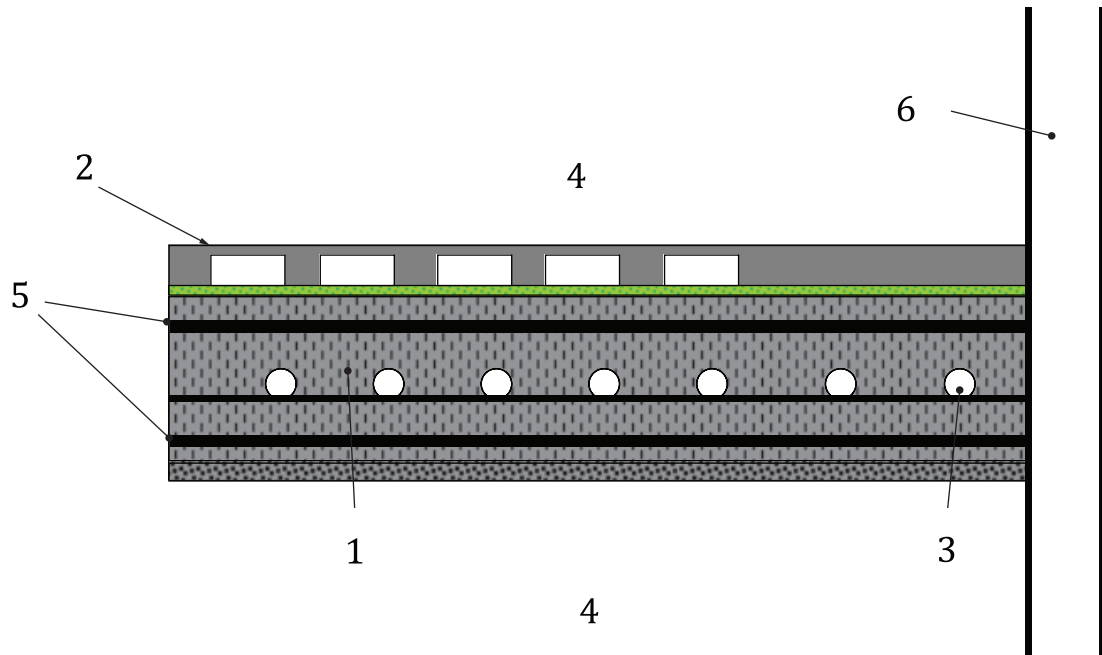
Symbol	Unit	Quantity
$P_{Cct}^{Max,h}$	W	Maximum cooling power reserved to the circuit under consideration in the $h$ -th hour
$P_{Cct,Spec}^{Max}$	W/m <sup>2</sup>	Maximum specific cooling power (per floor square metre)
$q_i$	W/m <sup>2</sup>	Inward specific heat flux
$q_u$	W/m <sup>2</sup>	Outward 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 <sup>2</sup>	Average specific cooling power
$R$	(m <sup>2</sup> ·K)/W	Generic thermal resistance
$R_{Add C}$	(m <sup>2</sup> ·K)/W	Additional thermal resistance covering the lower side of the slab
$R_{Add F}$	(m <sup>2</sup> ·K)/W	Additional thermal resistance covering the upper side of the slab
$R_{int}$	(m <sup>2</sup> ·K)/W	Internal thermal resistance of the slab conductive region
$R_{L,p}$	(m <sup>2</sup> ·K)/W	Conduction thermal resistance connecting the $p$ -th thermal node with the boundary of the (p+1)-th thermal node
$R_r$	(m <sup>2</sup> ·K)/W	Pipe thickness thermal resistance
$R_t$	(m <sup>2</sup> ·K)/W	Circuit total thermal resistance
$R_{U,p}$	(m <sup>2</sup> ·K)/W	Conduction thermal resistance connecting the $p$ -th thermal node with the boundary of the (p-1)-th thermal node
$R_W$	(m <sup>2</sup> ·K)/W	Wall surface thermal resistance
$R_{Wa}$	(m <sup>2</sup> ·K)/W	Water flow thermal resistance
$R_x$	(m <sup>2</sup> ·K)/W	Pipe level thermal resistance
$R_z$	(m <sup>2</sup> ·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
$\delta_j$	m	Thickness of the $j$ -th layer of the slab
$\Delta\theta$	K	Generic temperature difference

**Table 1** (continued)

Symbol	Unit	Quantity
$\Delta\theta_{\text{Comfort}}^{\text{Max}}$	K	Maximum operative temperature drift allowed for comfort conditions
$\Delta t$	s	Calculation time step
$\theta_A^h$	°C	Temperature of the air thermal node ("A") in the $h$ -th hour
$\theta_C^h$	°C	Temperature of the ceiling surface thermal node ("C") in the $h$ -th hour
$\Delta\theta_{\text{Comf}}^{\text{Max}}$	°C	Maximum operative temperature allowed for comfort conditions
$\theta_{\text{Comf,Ref}}$	°C	Maximum operative temperature allowed for comfort conditions in the reference case
$\theta_F^h$	°C	Temperature of the floor surface thermal node ("F") in the $h$ -th hour
$\theta_{\text{IW}}^h$	°C	Temperature of the core of the internal walls thermal node ("IW") in the $h$ -th hour
$\theta_{\text{IWS}}^h$	°C	Temperature of the internal wall surface thermal node ("IWS") in the $h$ -th hour
$\theta_{\text{MR}}^h$	°C	Room mean radiant temperature in the $h$ -th hour
$\theta_{\text{Op}}^h$	°C	Room operative temperature in the $h$ -th hour
$\theta_p^h$	°C	Temperature of the $p$ -th thermal node in the $h$ -th hour
$\theta_{\text{PL}}^h$	°C	Temperature of the pipe level thermal node ("PL") in the $h$ -th hour
$\theta_{\text{Slab}}^{\text{Av}}$	°C	Daily average temperature of the conductive region of the slab
$\theta_{\text{Wa,In}}^h$	°C	Water inlet actual temperature in the $h$ -th hour
$\theta_{\text{Wa,In}}^{\text{Setp},h}$	°C	Water inlet set-point temperature in the $h$ -th hour
$\theta_{\text{Wa,In,Ref}}^{\text{Setp}}$	°C	Water inlet set-point temperature in the reference case
$\theta_{\text{Wa,Out}}^h$	°C	Water outlet temperature in the $h$ -th hour
$\lambda_b$	W/(m·K)	Thermal conductivity of the material of the pipe embedded layer
$\lambda_j$	W/(m·K)	Thermal conductivity of the material constituting the $j$ -th layer of the slab
$\lambda_r$	W/(m·K)	Thermal conductivity of the material constituting the pipe
$\xi$	K	Actual tolerance in iterative calculations
$\xi_{\text{Max}}$	K	Maximum tolerance allowed in iterative calculations
$\rho_j$	kg/m <sup>3</sup>	Density of the material constituting the $j$ -th layer of the slab
$\omega$	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](#)).

**Key**

- 1 concrete
- 2 floor
- 3 pipes
- 4 room
- 5 reinforcement
- 6 window

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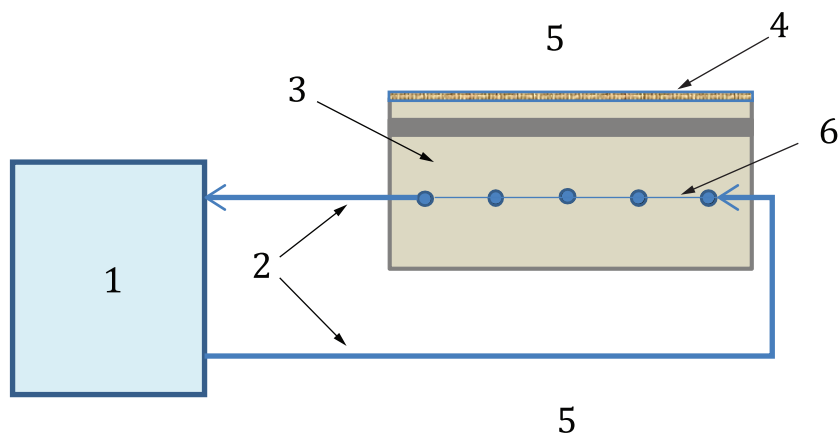
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**Figure 1 — Example of position of pipes in TABS**

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](#).

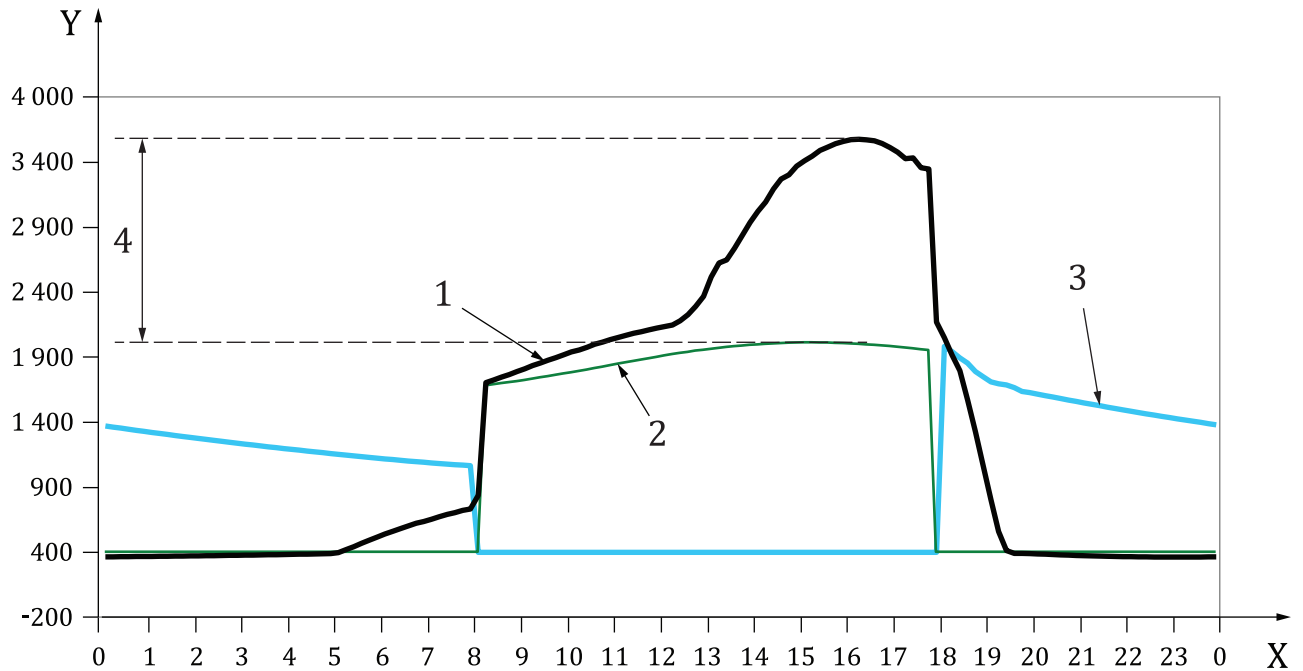


**Key**

- 1 heating and cooling equipment
- 2 hydraulic circuit
- 3 slab including core layer with pipes
- 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**  
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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.

**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

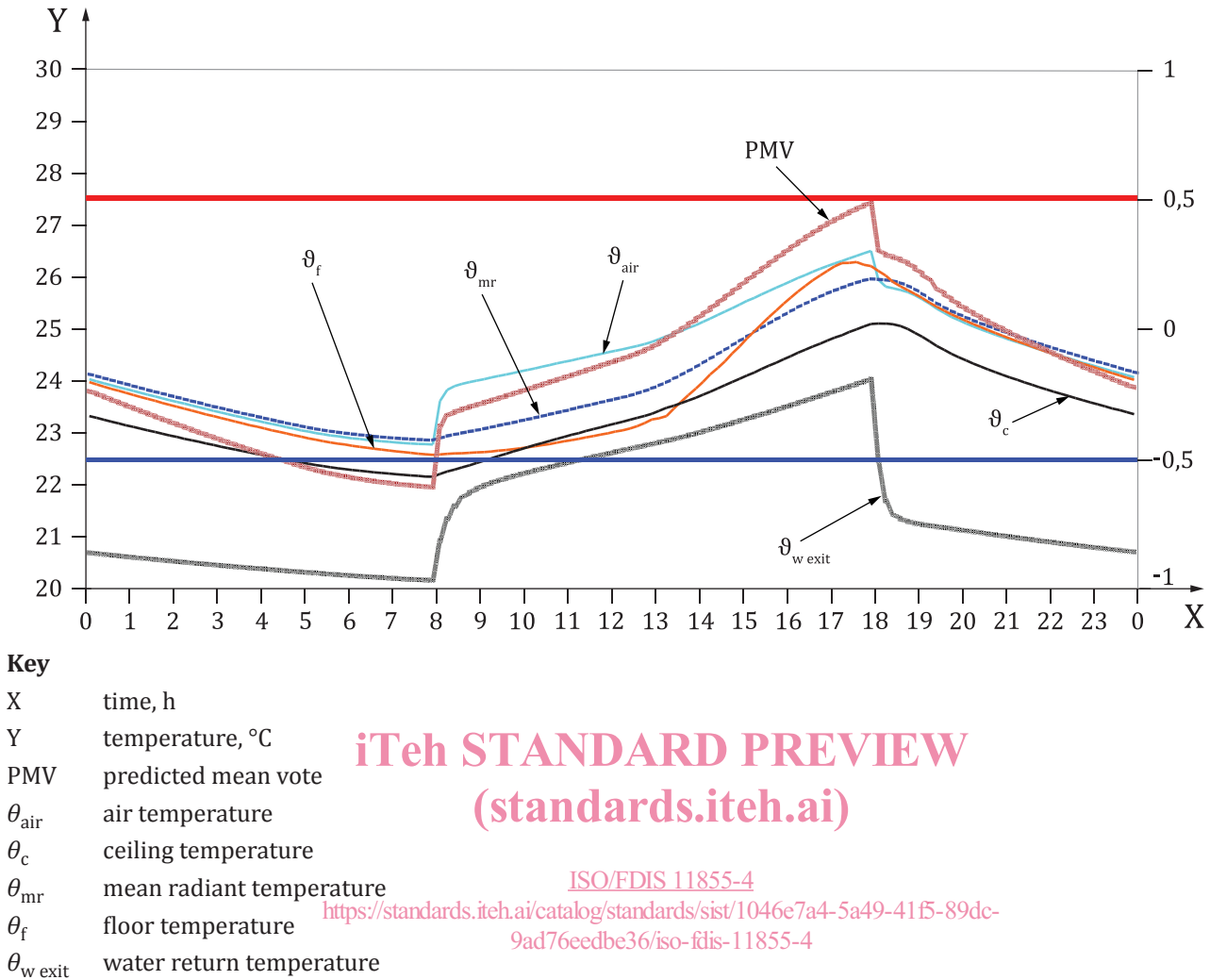
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**Figure 3 — Example of peak-shaving effect**

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](#)).



**Figure 4 — Example of temperature profiles and PMV values vs. 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 ( $R = 0,45 \text{ (m}^2\cdot\text{K)/W}$ ) 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) [ $\text{W/m}^2$ ], 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 [ $\text{Wh}/(\text{m}^2\cdot\text{d})$ ].

The lower diagram shows the cooling power [ $\text{W/m}^2$ ] 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 [ $\text{Wh}/(\text{m}^2\cdot\text{d})$ ].

The example shows that, for a maximum internal heat gain of 38  $\text{W/m}^2$  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

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

