
**Building environment design —
Design, test methods and control of
hydronic radiant heating and cooling
panel systems —**

Part 2:

**Determination of heating and cooling
capacity of ceiling mounted radiant
panels**

*Conception de l'environnement des bâtiments — Conception,
méthodes d'essai et contrôle des systèmes de panneaux hydroniques
radiants de chauffage et de refroidissement —*

*Partie 2: Détermination de la capacité de chauffage et refroidissement
des panneaux radiants montés au plafond*



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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).

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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 205, *Building environment design*.

A list of all parts in the ISO 18566 series can be found on the ISO website.

Introduction

The radiant heating and cooling system consists of heat emitting/absorbing, heat supply, distribution, and control systems. Typical applications are low temperature radiant heating and high temperature radiant cooling. They are classified as embedded radiant heating and cooling systems and prefabricated radiant heating and cooling panel systems.

While ISO 11855 is for embedded radiant heating and cooling systems without an open air gap, ISO 18566 is for radiant heating and cooling panel systems with an open air gap. Because the system specifications for ISO 18566 are different from those of ISO 11855, it was necessary to develop separate ISO standards regarding the design and test methods of the cooling and heating capacity and control.

ISO 18566-1 specifies the comfort criteria, technical specifications and requirements which should be considered in the manufacturing and installation of radiant heating and cooling systems. ISO 18566-2 provides the test facility and test method for heating and cooling capacity of ceiling mounted radiant panels. ISO 18566-3 specifies the design considerations and design processes of ceiling mounted radiant panels. ISO 18566-4 addresses the control of ceiling mounted radiant heating and cooling panels to ensure the maximum performance which was intended in the design stage when the system is actually being operated in a building.

ISO 18566 does not cover the panels that are embedded into the ceiling, wall or floor structure.

This document deals with the determination of heating and cooling capacity of ceiling mounted radiant panels. In [Clause 5](#), the boundary conditions for the heating and cooling capacity test are described. In [Clause 6](#), the test chamber and the output from the test are defined.

This document is partly based on EN 14240, EN 14037 and ASNI/ASHRAE Standard 138.

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Building environment design — Design, test methods and control of hydronic radiant heating and cooling panel systems —

Part 2:

Determination of heating and cooling capacity of ceiling mounted radiant panels

1 Scope

This document defines technical specifications and requirements of free hanging (suspended) heating and dry cooling only surfaces with an air gap between construction and the emitter (not embedded) with or without an insulation fed with water at temperatures below 120 °C connected with a centralized heating and/or cooling supply source intended to be installed in buildings.

Ceiling mounted radiant panels covered by this document are limited to a width from 0,3 m up to 1,5 m.

This document also defines the additional common data that the manufacturer provides to the trade, in order to ensure the correct application of the products.

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/IEC 18566-1, *Building environment design — Design, test methods and control of hydronic radiant heating and cooling panel systems — Part 1: Definition, symbols, technical specifications and requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18566-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

4 Symbols

For the purposes of this document, the symbols in ISO 18566-1 apply.

5 Test booth

5.1 Radiant temperature asymmetry

The booth for testing ceiling mounted radiant panels shall be constructed in a way that all six surrounding surfaces can be chilled.

Walls, ceiling and floor shall have smooth inside surfaces covered with a coat of mat paint, having a degree of emissivity of minimum 0,9.

The test booth construction shall be sufficiently tight to prevent air infiltration.

Heating case

The cooling system is to be carried out in order that the temperature difference between the six surrounding inside surfaces of the test booth is not higher than 0,5 K. The temperature difference between inlet and outlet shall not be higher than 0,5 K. That condition shall be maintained at the tests for the determination of the characteristic equation.

Cooling case

For covering the cooling capacity, the test booth will be heated with a number of electrical heated cooling load simulators (see [Annex B](#)) which are positioned on the floor of the test booth (see [Figures B.1](#) and [B.2](#)).

Differing from these definitions, the surfaces, floor and ceiling of the test booth shall be insulated in the way that the average heat flow in those surfaces is lower than 0,40 W/m² during the test. This heat flow shall be determined by preliminary calibration tests of the booth or by calculations.

The reference temperature during the measurement shall be 32 °C ± 0,5 K in the steady condition for a minimum of 30 min. The temperature(s) of inner surfaces of walls, floor and ceiling of the test booth (under the insulation) shall be controlled and be kept on a value, which is necessary to guarantee a maximum temperature difference between these surfaces and the reference temperature of less than 1,0 K.

The test booth will be heated with six electrical heated cooling load simulators, which are positioned on the floor of the test booth. The output of each simulator shall not exceed 180 W and shall be continuously adjustable, e.g. with an adjustable transformer or a thyristor. Each simulator shall have an identical heat output and the same number of bulbs.

The housing of the simulators consists of painted steel sheet. The emissivity of the inside and outside surface shall be at least 0,9. The active power of the simulators shall be measured with a measuring instrument of the accuracy class 1,0 % or better.

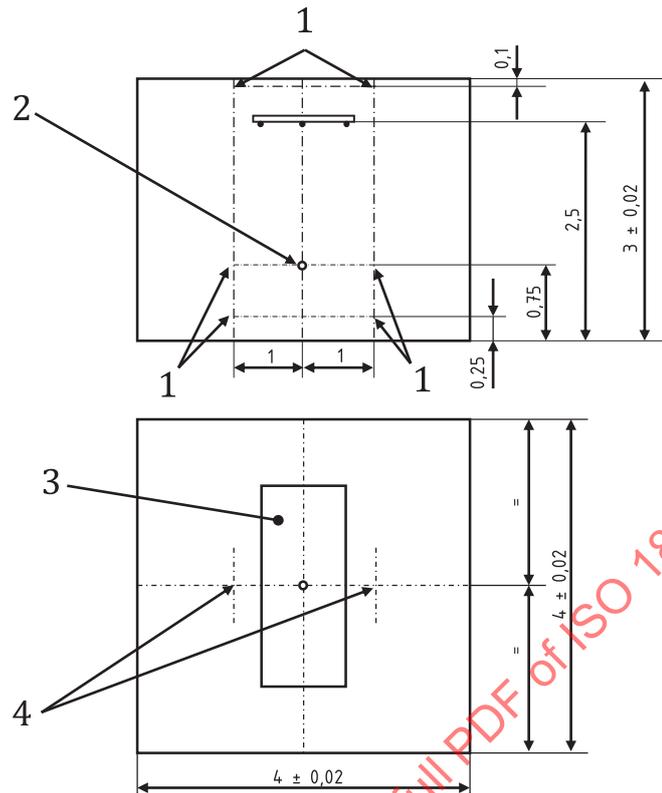
5.2 Temperature measuring points

Reference room temperature

The reference room temperature is measured at a height of 0,75 m above the floor of the test booth by means of a globe thermometer. The measuring point is situated on the vertical axis through the central point of the ceiling mounted radiant panel. A temperature sensor with blackened light metal sphere (diameter 150 mm, emissivity 0,9) is used. The measuring point is arranged in the centre of the sphere. The penetration of the temperature sensor through the surface of the sphere runs horizontally and is air tight. The hollow sphere is attached to the temperature sensor.

Air temperature

The air temperature is measured with sensors protected against radiation. The measuring points are situated on two vertical axes at three different heights as shown in [Figure 1](#).



Key

- 1 air temperature measuring points
- 2 reference room temperature measuring point
- 3 ceiling mounted radiant panel
- 4 axes of air temperature measuring points

The dimension of the reference room should follow [Figure 1](#), but national requirements should be also taken into account.

Figure 1 — Arrangement of measuring points for the reference room temperature and for air temperature

Surface temperature of the inside surfaces

The surface temperatures of the inside walls are calculated as average value of the inlet and outlet water temperature of each single surface wall.

5.3 Verification of test installation, repeatability and reproducibility

All test installations shall be verified for:

- **constructional conformity:** any statement concerning thermal outputs shall be accompanied by a statement indicating the test conditions in which the stated outputs have been obtained;
- **repeatability:** the repeatability precision shall be within an allowed tolerance s_0 when testing a single master panel in the same test installation at short or long intervals. The testing laboratory will use its own master panel (secondary set) to determine the repeatability tolerance s_0 of the test installation. Using this master panel, heat output tests shall be carried out. The latest test for repeatability shall not have taken place longer than 6 months before a thermal heat output test. The repeatability shall be tested every 12 months in minimum. To prove the repeatability precision of a test laboratory, the results of five consecutive tests at the start of the test installation shall be within a tolerance range $s_0 = 20 \text{ W}$;

- **reproducibility:** the reproducibility shall be proved by using the primary set of master panels. The test results shall be within the tolerance $s_m = \pm 20$ W of the $\Phi_{M,S}$ value of each master panel.

The test laboratories have to prove the reproducibility in periodical tests.

6 Test

6.1 General

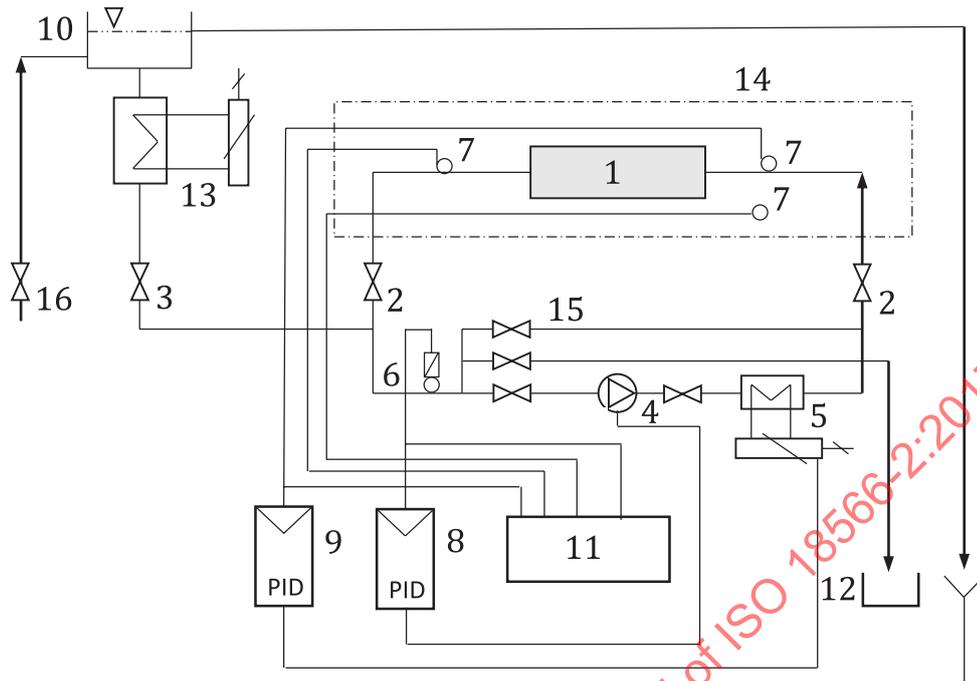
The aim of the thermal output test is to establish the standard characteristic equation of a ceiling mounted radiant panel by determining the related values of thermal output and cooling capacity and temperature difference. Neither of these quantities can be measured directly, but shall be calculated using the values of other measurable quantities, either directly or with additional information (calibration test, material properties table), by using mathematical relationships.

6.2 Test method

The thermal output Φ_{me} is calculated based on the water flow rate q_m and the measured temperatures h_1 and h_2 as shown in [Formula \(1\)](#). These temperatures are used to calculate the specific enthalpies as determined by the international steam tables at a reference water pressure of 120 kPa:

$$\Phi_{me} = q_m (h_1 - h_2) \quad (1)$$

The water flow rate is measured directly by a calibrated flow-meter in a closed water circuit or calculated using the mass of the water m , collected in a measuring vessel, and the relevant time interval τ .

**Key**

- | | | | |
|---|--|----|--|
| 1 | panel in the test booth | 9 | control unit for flow temperature |
| 2 | water circuit for measurement | 10 | container with overflow for calibration device |
| 3 | connection of the calibration device to the measuring circuit | 11 | recording and evaluating instruments |
| 4 | circulating pump in the measuring circuit (controlled) | 12 | collecting and draining installation for calibrating measurement |
| 5 | electric heating element in the measuring circuit for flow temperature control | 13 | heating device for calibrating measurement |
| 6 | mass flow measuring instrument | 14 | test booth |
| 7 | temperature measuring points | 15 | bypass |
| 8 | control unit for mass flow | 16 | water supply for calibration device |

Figure 2 — Basic diagram of test installation with continuous measurement of the mass flow (weighing method) and with a device for calibrating the measuring instrumentation

The bulk temperature of the water at inlet and outlet shall be measured with a device which ensures a sufficient accuracy.

All temperatures which do not serve for the determination of the thermal output shall be measured with an accuracy of $\pm 0,1$ K.

The maximum uncertainty in measuring the thermal output shall not exceed ± 10 W.

The air pressure is measured with a tolerance of ± 2 hPa.

The natural convection inside the test booth shall not be influenced by additional means.

6.3 Dimension and construction of the test samples

The active length of the ceiling mounted radiant panels without the connection components shall be within the range of 2,9 m to 3,1 m. The width shall be within the range of 0,3 m to 1,5 m. The construction length including the connection components shall be a maximum of 3,5 m. No elements which could increase the heat output shall be added to the linkage between the active length and the collectors/headers.

6.4 Selection of the models to be tested for determining the thermal output of a type

For determining the thermal output of a type, the models with the smallest and largest width within the range are to be tested at least. Interpolation of thermal output and exponent is allowed if the proportion of width of two tested panels does not exceed 2. Interpolation shall be linear.

6.5 Manufacturer documents for the test samples

The manufacturer shall provide for each test sample a drawing containing all dimensions and other characteristics which will have an influence on the thermal output. This also includes all details about welding or other methods of bonding.

The drawing shall also contain all the details of material used and of the nominal wall thickness of wet and dry surfaces, as well as the specification of the surface treatment applied.

The manufacturer shall declare that the sample supplied has been manufactured with the same methods and materials as the models of the standard production.

In cases where the test sample has not been manufactured by the applicant, a written declaration of product identity, which will be added to the test report of the test laboratory, has to be submitted.

Instead of information concerning the manufacturer and the designation of product, reference to the abovementioned declaration shall be made in the test report.

6.6 Arrangement of the sample in the test booth

The ceiling mounted radiant panel to be tested shall be installed horizontally. It shall be installed symmetrical to the centre axes of the test booth. The lowest point of the radiating surface shall be $(2,5 \pm 0,02)$ m above the floor. It shall be installed with the connection components.

When measuring the thermal output of the active length, these components shall be provided completely insulated. The insulation has to be thick all-over 40 mm. If the distance between the header and active length is below 40 mm, the insulation has to cover the respective part of the active length. When determining the thermal output of the module, only the free part of the active length will be considered. When determining the thermal output of the connecting components, the output of the effective active length will be calculated with the characteristic equation.

The upper insulation to be provided by the laboratory for the test of the standard output is defined as follows: layer of 40 mm mineral wool with vertical fibre, covered with aluminium foil, with heat conductivity of 0,04 W/mK at 40 °C and density of 25 kg/m³ at minimum. The insulation shall be placed on the upper side of the test panel without any interruption, aluminium foil at top. Upwards standing components like braces and suspension bars etc. have to be respectively insulated.

In ceiling mounted radiant panels with a heat-insulating layer in combination with active heating surface on top, the upper insulation as described before has to be installed in addition for the measurement of the standard thermal output.

After installation and connection to the measuring circuit, the test sample and the water circuit shall be carefully vented. During the test, the measuring circuit shall be free of air inclusions. The procedure of venting is to be described in the working instructions of the test laboratory.

6.7 Test procedure

6.7.1 Test

The measuring of the thermal output of a model shall be done with two tests. At both tests, the upper insulation shall be provided.

Test 1 is made to evaluate the thermal output of the active length. The connection components shall be insulated.

Test 2 is to evaluate the total thermal output. Therefore, the insulation of the connection components shall be removed.

6.7.2 Mass flow

The water flow rate shall be regulated so that a Reynolds value $Re = 4\,500 \pm 500$ results in the pipes of the ceiling mounted radiant panel at a water temperature of 50 °C. During the test for measuring the three points of the characteristic equation, the mass flow rate shall be constant at each measuring point and shall not differ more than 5 % from one point to another.

6.7.3 Test temperature — Heating case

A reference room temperature of 20 ($\pm 0,5$) °C in the steady-state conditions has to be held for 0,5 h during the measurement.

To determine the characteristic equation, measurements are carried out at three different mean temperatures of the ceiling mounted radiant panel. These mean temperatures shall be calculated from the respective inlet and outlet temperatures. They shall be within the following ranges:

- 30 °C to 34 °C;
- 48 °C to 52 °C;
- 68 °C to 72 °C;
- 88 °C to 92 °C.

6.7.4 Test temperature — Cooling case

The measuring shall be carried out at a reference temperature of 32 °C and a temperature difference of 15 K $\pm 0,5$ K. It shall be guaranteed that the surface temperature is higher than the dew point during the measurement.

6.7.5 Steady-state conditions

Steady-state conditions shall be maintained throughout the duration of the test, as far as both the primary fluid circuit and the ambient conditions in the test installation are concerned (see [Figure 2](#)). Parameters are to be monitored at regular intervals. Steady-state conditions are deemed to exist when the standard deviations of all the readings (not less than 12 sets in minimum of 6 min) amount to less than half of the ranges specified below:

water and air temperature	$\pm 0,1$ K (heating case)
	$\pm 0,05$ K (cooling case)
water flow rate	1,0 %

The measuring results shall only be used if the thermal balance for test sample, simulators and heat transmission does not differ through the test space enclosures more than 5 % from the total cooling capacity of the test sample according to [Formula \(2\)](#).

$$|(\Phi_B + \Phi_S + \Phi_{me})| \leq 0,05 \Phi_{me} \quad (2)$$

where, in [Formula \(3\)](#),

$$\Phi_B = \sum_{i=1}^6 A_i \cdot U_i (\theta_{w,i} - \theta_{ref}) \quad (3)$$

where

Φ_S is the total thermal output of simulators;

Φ_{me} is the measured output.

6.7.6 Correction due to the air pressure

To take in account air pressures deviating from $p_s = 101,325$ kPa, the measured output Φ_{me} shall be corrected as follows:

$$\Phi = \Phi_{me} \left[0,65 + 0,35 \left(\frac{p_s}{p} \right)^{0,4} \right] \text{ (heating case)} \quad (4)$$

$$\Phi_{Cme} = \Phi_{me} \left[0,5 + 0,5 \left(\frac{p_s}{p} \right)^{0,4} \right] \text{ (cooling case)} \quad (5)$$

6.7.7 Results of measurement — Characteristic equation

Heating case:

Having been corrected according to [Formulae \(4\)](#) and [\(5\)](#), the values of the thermal output are plotted over the measured values of temperature difference and the characteristic equation, as well as its mathematical function, is determined. The formula for the characteristic of a model reads as shown in [Formulae \(6\)](#) and [\(7\)](#):

$$\text{Characteristic equation of the active length } \Phi_{act} = K_{act} \cdot \Delta\theta^{n_{act}} \quad (6)$$

$$\text{Characteristic equation of the total length } \Phi_{tot} = K_{tot} \cdot \Delta\theta^{n_{tot}} \quad (7)$$

The constants K_{act} and K_{tot} and the exponents n_{act} and n_{tot} are determined by regression as shown in [Formulae \(8\)](#) and [\(9\)](#):

$$\text{The characteristic equation: } \Phi = K \cdot \Delta\theta^n \quad (8)$$

$$\text{becomes in logarithmic coordinates: } \log \Phi = \log K + n \cdot \log \Delta\theta \quad (9)$$

Applying the least squares method, the $\log K$ and n values are obtained as shown in [Formulae \(10\)](#) and [\(11\)](#):

$$\log K = \frac{\sum (\log \Phi) \cdot \sum [(\log \Delta\theta)^2] - \sum (\log \Delta\theta \cdot \log \Phi) \cdot \sum (\log \Delta\theta)}{N \sum [(\log \Delta\theta)^2] - (\sum \log \Delta\theta)^2} \quad (10)$$

$$n = \frac{N \sum [(\log \Delta\theta \cdot \log \Phi)] - \sum (\log \Delta\theta) \cdot \sum (\log \Phi)}{N \sum [(\log \Delta\theta)^2] - (\sum \log \Delta\theta)^2} \quad (11)$$

where

N is the number of test points.

The standard output is calculated from the function of the characteristic equation.

The characteristic equation of the connection components is formed by subtraction of the characteristic equation of the total length and the one of the active length. The subtraction is carried out for 30 K, 50 K and 70 K. The constant K_{comp} and the exponent n_{comp} are determined in the same way as for the other formulae.

Cooling case

The standard cooling capacity results from the corrected value of the output according to [Formula \(5\)](#) as per [Formula \(12\)](#):

$$\Phi_{\text{CS}} = \Phi_{\text{Cme}} \left(\frac{\Delta\theta_{\text{CS}}}{\Delta\theta_{\text{me}}} \right)^{n_{\text{Cact}}} \quad (12)$$

assuming a defined exponent of $n_{\text{Cact}} = 1,1$.

The standard cooling capacity with a temperature difference of 15 K can be recalculated to other insufficient temperatures differing from the standard temperature difference analogical to [Formula \(12\)](#).

The nominal cooling capacity is calculated with the nominal temperature difference (8 K) as shown in [Formula \(13\)](#).

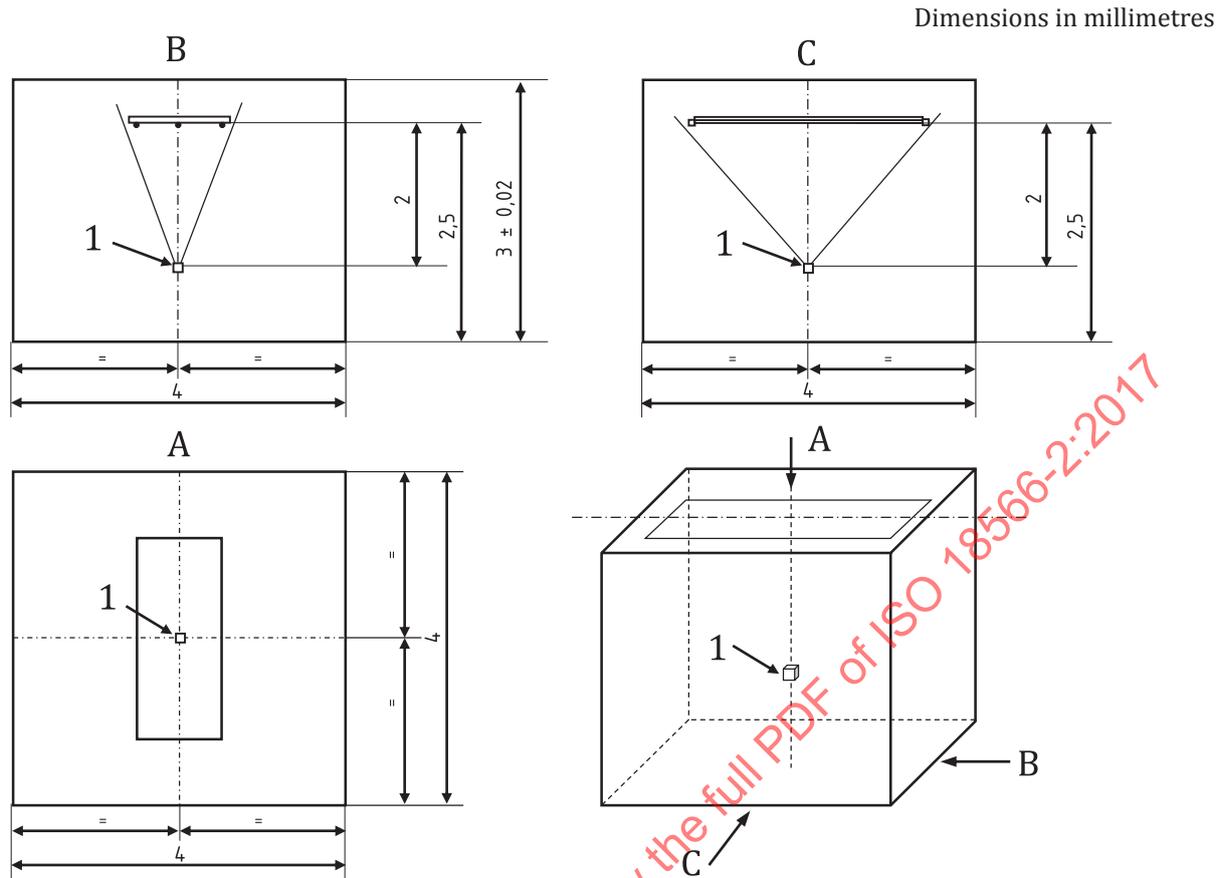
$$\Phi_{\text{CN}} = \Phi_{\text{CS}} \left(\frac{\Delta\theta_{\text{CN}}}{\Delta\theta_{\text{CS}}} \right)^{n_{\text{Cact}}} \quad (13)$$

6.7.8 Testing of mean surface temperature and the emissivity of the panel

The mean surface temperature shall be determined by an infrared (IR) system with the following features: automatic mean temperature of the measured surface including the emissivity, the distance and the ambient temperature.

The mean surface temperature shall be determined with the IR system for each testing point.

The IR system shall be installed with the sensitive probe directed towards the central vertical axis of the ceiling mounted radiant panel (see [Figure 3](#)).



Key

- 1 IR system
- A top view
- B side view over the width of the ceiling panel
- C side view over the length of the ceiling panel

Figure 3 — Arrangement of the IR system and the ceiling panel in the test booth during determination with only one testing point

The distance between the surface of the ceiling mounted radiant panel and the sensor shall be 2 m. The field of view shall be not less than 80° over the length and not less than 60° over the width of the panel. The tolerance of mean surface temperature shall be not more than 1,0 K. The results of the determination of the radiant output shall be reported.

Practical experiments under real conditions and simulation exercises indicate that test booth results understate output from radiant ceiling mounted panels by a factor of about 10 %. In order to ensure that designers are able to use test data for correct sizing of products, a correction factor is applied to test data to give rated thermal output Φ_D . The factor of 1,1 shall be introduced in the characteristic equation. The rated thermal output shall be taken from this curve in correspondence of standard temperature difference.

The radiant output of the tested panel can be calculated for each measuring point as shown in [Formula \(14\)](#):

$$\Phi_{\text{rad}} = \sigma \cdot \varepsilon_{\text{rp}} \cdot (\theta_{\text{rp}}^4 - \theta_{\text{w}}^4) \cdot A_{\text{rp}} \quad (14)$$

The referred percentage of radiant output is calculated for each measuring point as shown in [Formula \(15\)](#):

$$r = \frac{\Phi_{\text{rad}}}{\Phi_{\text{act}}} \cdot 100 \quad (15)$$

The determination of the emissivity shall be carried out with samples of the original sheet covered with the surface coating used at production. The test shall be done by certified laboratories.

7 Test report

The laboratory shall prepare a test report (see [Annex A](#)) based on the procedures and calculation contained in this document.

The laboratory may only prepare a test report with reference to this document if the test sample is a pre-fabricated heat-transmitting device in the form of a heating or cooling element with width of 0,3 m up to 1,5 m fitted with connection components and designed to operate on water flow heating facilities and/or in cooling systems.

The following data shall be stated in the test report:

- name and address of the test institute;
- location of test (if different from the test institute);
- name and address of the customer;
- identification of the test method used;
- description of the test booth;
- identification of the test samples including trademark, model number, dimensions;
- dates of testing;
- documents of the manufacturer (drawing no., report of the pressure test, report of the factory test), confirmation of the producer or declaration of product identity;
- test results:
 - results of the resistance to pressure test;
 - control of the general construction specifications;
 - control of the dimensional tolerances; all dimensions of the test sample shall be documented with the nominal dimension, the measured dimension, nominal tolerance and the measured differences in a table;
 - test data including, for example, water temperatures, air temperatures, globe temperature, water flow rate, corresponding Reynolds number at 50 °C (heating case);
 - standard total output and the characteristic equation of the tested panel;
 - standard output and the characteristic equation of the active length of the tested panel;
 - standard output and the characteristic equation of connection components of the tested panel;

- standard modular output and exponents of the tested panel and the interpolated/calculated panels;
- rated thermal output of the tested panel and the interpolated/calculated panels;
- for characteristic equation with deviations from the standard characteristic equation, an exact description of the boundary condition: parameters, thermal output values of standard temperature difference, equation for the characteristic.

The constant K and the exponent n should be represented with three decimal places, the standard output with one decimal place. Performance appointing temperatures (water, globe) have to be stated with two decimal places and all other temperatures with one decimal place.

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Annex A (informative)

Tables of the test report for heating and cooling

Table A.1 — Standard thermal outputs and exponents n of the models

Model	Width m	Active length m	Thermal output of the active length W	Exponent n	Standard modular thermal output W/m	Rated modular thermal output W/m

Table A.2 — Results of Tests 1 and 2 (for each tested model)

	Symbols	Unit	Measuring points		
			1	2	3
Air pressure	p	kPa			
Reference room temperature	θ_{ref}	°C			
Inlet water temperature	θ_1	°C			
Outlet water temperature	θ_2	°C			
Water temperature drop	$\theta_1 - \theta_2$	K			
Inlet water enthalpy	h_1	J/kg			
Outlet water enthalpy	h_2	J/kg			
Enthalpy difference	$h_1 - h_2$	J/kg			
Mean water temperature	θ_m	°C			
Temperature difference	$\Delta\theta$	K			
Water flow rate	q_m	kg/s			
Measured output	Φ_{me}	W			
Output corrected for barometric pressure	Φ	W			

Characteristic equation of the tested model: $\Phi = K_m \times \Delta\theta^n$

where

$K_m = \dots\dots\dots$

$n = \dots\dots\dots$

Table A.3 — Report of the determination of the characteristic equation from the connecting components

	Unit	Calculation points		
		1	2	3
Temperature difference	K	30 K	50 K	70 K
Total output (Test 2)	W			
Output of the active length (Test 1)	W			
Output of the connection components	W			