BRITISH STANDARD

BS EN 14240:2004

Ventilation for buildings — Chilled ceilings — Testing and rating

The European Standard EN 14240:2004 has the status of a British Standard

ICS 91.140.30

British Standards

National foreword

This British Standard is the official English language version of EN 14240:2004.

The UK participation in its preparation was entrusted to Technical Committee RHE/2, Air distribution and air diffusion, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 January 2004

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 18, an inside back cover and a back cover.

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Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 43362 9

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14240

January 2004

ICS 91.140.30

English version

Ventilation for buildings - Chilled ceilings - Testing and rating

Ventilation de bâtiments - Plafonds refroidis - Essais et évaluation

Lüftung von Gebäuden - Kühldecken - Prüfung und Bewertung

This European Standard was approved by CEN on 3 November 2003.

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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Ref. No. EN 14240:2004: E

Contents

Foreword

This document (EN 14240:2004) has been prepared by Technical Committee CEN/TC 156 "Ventilation for buildings", the secretariat of which is held by BSI.

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 July 2004, and conflicting national standards shall be withdrawn at the latest by July 2004.

Annex A is informative.

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

1 Scope

This European Standard specifies test conditions and methods for the determination of the cooling capacity of chilled ceilings and other extended chilled surfaces.

The purpose of the standard is to give comparable and repeatable product data.

The test method applies to all types of surface cooling systems using any medium as energy transport medium.

NOTE The result is valid only for the specified test set up. For other conditions (i.e. different positions of heat loads, forced flow around the test object, variations in surface area) the producer should give guidance based on full-scale tests.

This standard refers to water as the cooling medium throughout, however wherever water is specified any other cooling medium can also be used in the test. Where air is the transport medium this air may not be discharged into the test room. In addition, this standard refers to chilled surfaces and where "surfaces" are specified this should be taken to include ceiling, wall or floor as appropriate.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendment to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 12792, *Ventilation for buildings – Symbols, terminology and graphical symbols.*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions in EN 12792 together with the following apply.

3.1.1
chilled surfaces
surfaces that are part of the room periphery (such as ceiling, walls and floor) and cooled with water

3.1.2
test room
room in which the test object is mounted

3.1.3
room air temperature (θ_a)
air temperature measured with radiation shielded sensor

3.1.4
globe temperature (θ_g)
dry resultant temperature of the room, measured with a temperature sensor placed in the centre of the globe as in 4.3

3.1.5
reference room temperature (θ_r)
average of the measured globe temperature, measured in the middle of the room at a height of 1,1 m above the floor, during the test period

3.1.6
cooling water flow rate (q_w)
average of the measured water flow rate during the test period

3.1.7
cooling water inlet temperature (θ_{w1})
average of the measured water temperature into the test object during the test period

3.1.8
cooling water outlet temperature (θ_{w2})
average of the measured water temperature out of the test object during the test period

3.1.9
mean cooling water temperature (θ_w)
the mean value of the sum of the cooling water inlet and outlet temperatures

3.1.10
temperature difference ($\Delta\theta$)
difference between reference room temperature and mean cooling water temperature [$\Delta\theta=\theta_r-\theta_w$]

3.1.11
specific heat capacity (c_p)
heat required to raise the temperature of a unit mass of the cooling medium by 1 K

NOTE c_p for water = 4,187 $kJkg^{-1}K^{-1}$ at 15°C.

3.1.12
test room area (A_t)
area of the test room surface (ceiling, wall or floor) on which the test object is located (see Figure 1).

3.1.13
installation area (A_i)
projection of the total test object onto the room surface, including all intermediate surface channel supports and air gaps, associated with normal panel installation (see Figure 1)

3.1.14
panel area (A_p)
projection of the panels onto the room surface, excluding intermediate surface channel supports and air gaps associated with normal panel installation (see Figure 1)

3.1.15
active area (A_a)
reference area to calculate the specific cooling capacity of the test object (see Figure 2)

3.1.16
cooling capacity (P)
total cooling capacity of the test object calculated from the measured cooling water flow rate and the cooling water temperature rise

3.1.17
specific cooling capacity of a chilled surface (P_a)
cooling capacity divided by the active area of the chilled surface

3.1.18
nominal temperature difference ($\Delta\theta_N$)
temperature difference between the reference room temperature and the mean cooling water temperature

3.1.19
nominal cooling water flow rate (q_{wN})
flow rate that gives a cooling water temperature rise of (2 ± 0,2) K at the nominal temperature difference of 8 K

3.1.20
nominal cooling capacity (P_N)
cooling capacity calculated from the curve of best fit for the nominal cooling water flow rate at the nominal temperature difference ($\Delta\theta_N$)

3.2 Symbols and units

For the purposes of this European Standard, the symbols in CR 12792 together with those given in Table 1 apply.

Table 1 – Symbols and units

Symbol	Quantity	Unit
A_a	Active area	m^2
A_i	Projection area of the total test object onto the room surface	m^2
A_p	Projection area of the panels on to the room surface	m^2
A_t	Area of test room surface	m^2
c_p	Specific heat capacity	$KJkg^{-1}K^{-1}$
h	Height from floor to under side of false ceiling [$h = h_r - h_v$]	m
h_r	Inside room height including void depth	m
h_v	Void depth	m
l_r	Inside room length	m
n_r	Number of dummies in one row	
P	Total cooling capacity [$P = c_p \cdot q_m \cdot (\theta_{w2} - \theta_{w1})$]	W
P_a	Specific cooling capacity re active area [$P_a = P/A_a$]	Wm^{-2}
P_i	Specific cooling capacity re projection area of total test object [$P_i = P/A_i$]	Wm^{-2}
P_t	Specific cooling capacity re area of test room surface [$P_t = P/A_t$]	Wm^{-2}
P_B	Total thermal transfer through all boundaries	W
P_N	Nominal cooling capacity	W
$P(R_a)$	Statement of measured performance for tested active area - R_a - For example expressed as $P(85)$	Wm^{-2}
P_s	Total heating capacity of the dummies	W
P_t	Specific cooling capacity [$P_t = P/A_t$]	Wm^{-2}
q_m	Cooling medium mass flow [$q_m = \rho_w . q_w$]	Kgh^{-1}
q_w	Cooling medium flow rate	Lh^{-1}
R_a	Active area ratio [A_a / A_i x 100]	%
s	Thickness of insulation	m
w_r	Inside room width	m
ρ_w	Density of cooling medium at θ_w	Kgl^{-1}
θ_a	Room air temperature	°C
$\Delta\theta$	Temperature difference	K
$\Delta\theta_N$	Nominal temperature difference [$\Delta\theta_N = \theta_r - \theta_w = 8K$]	K
θ_g	Globe temperature	°C

θ_r	Reference room temperature	°C
θ_{W1}	Cooling water inlet temperature	°C
θ_{W2}	Cooling water outlet temperature	°C
θ_W	Mean cooling water temperature [θ_w=0,5·(θ_{w1}+θ_{w2})]	°C
λ	Thermal conductivity	$Wm^{-1}K^{-1}$

4 Test method

4.1 Principle

The cooling capacity of the test object shall be determined from measurements of the cooling water flow rate, and the cooling water temperature rise, under steady state conditions. The cooling capacity shall be presented as a function of the temperature difference between the reference room temperature and the mean cooling water temperature.

The measurements shall be performed in an airtight room, to the requirements of 4.2, with controlled temperatures on the inside surfaces and with negligible heat flow through the perimeters of the room. To balance the cooling capacity of the test object, heating is supplied in the test room by means of a number of electric heated dummies placed on the floor within the test room. In order to obtain reproducible results, the dummies shall be placed in pre-determined positions as described in 4.4.

4.2 Test room

The floor area of the test room shall be between 10,0 m^2 and 21,0 m^2.

The ratio of width to length of the test room shall be not less than 0,5 and the inside height shall be between 2,7 m and 3,0 m.

The recommended inside dimensions are a length of 4 m, a width of 4 m and a height of 3 m.

NOTE The test room specification enables the use of test rooms in accordance with EN 442 for the testing of chilled surfaces. The dimensions of the test room are given as a recommendation. It is permitted for the test room dimensions to deviate from the recommended dimensions.

The test room shall be sufficiently tight to minimise flow from the ambient air outside which shall not exceed 0.8 $ls^{-1}m^2$ of the perimeter surface at a pressure difference of 50 Pa (note includes floor walls and ceiling). The air within the test room shall not be influenced by any forced air flow.

The inner wall and floor temperature can be controlled by different methods, for instance:

a) water panels covering all the outside surfaces with circulating temperature controlled water;

b) forced air flow circulation, temperature controlled with electric heaters, in an external room.

The walls, floor and ceiling of the test room shall be insulated in such a way, that during the test the average heat flow through these surfaces is less than 0,40 Wm^{-2}. This heat flow shall be determined by means of preliminary calibration tests of the room, or by calculation.

The radiation emission rate of the inner surfaces of the room shall be at least 0,9.

It is recommended that fixed temperature sensors should be installed at least in the centre of each room surface.

NOTE It is assumed that the insulation is placed inside, however if placed outside, the position of the temperature sensor should be in the outer surface of the insulating layer and covered locally with required insulation to ensure accurate measurement of the surface temperature.

4.3 Instrumentation

The heating of the test room is provided by means of a number of electrically heated dummies (see Figure 5) placed on the floor inside the test room.

The power to each dummy shall not exceed 180 W and shall be continuously adjustable, for instance with a variable voltage transformer or with thyristor.

The number of dummies shall be even and chosen so that each dummy covers an average floor area of 0,9 m^2 to 1,35 m^2 (i.e. the maximum heat load is 200 Wm^{-2}).

The casing of the dummies consists of lacquered steel sheet. The emission rate of the inner and outer surface should be at least 0,9. The real electric power to the dummies shall be measured with a wattmeter of quality class 1,0 % or better.

Air temperatures shall be measured by radiant shielded sensors with an accuracy of measurement equal to, or better than, ± 0,1 K.

Surface temperatures shall be measured by sensors fixed to the surface, which have an accuracy of measurement equal to, or better than, ± 0,1 K.

Globe temperature shall be measured with a sensor with accuracy of measurement equal to, or better than, ± 0,1 K placed in the centre of a black globe with diameter 60 mm - 150 mm, according to ISO 7726.

The temperature of the water into and out of the test object shall be measured by sensors, placed in the water flow immediately before and after the test object, with an accuracy of measurement equal to, or better than, ± 0,1 K. These sensors shall be calibrated to provide an accuracy of measurement of the cooling water temperature rise within ± 0,02 K. The sensor placed in the globe shall be calibrated together with the water temperature probes to give an accuracy of measurement of the temperature difference between the reference room temperature and the inlet and outlet water temperatures equal to, or better than, ± 0,05 K.

The water flow rate shall be measured with a flow meter calibrated by a weighing method to an accuracy equal to, or better than, ± 0,5 %.

The dew point temperature of the test room air shall be measured using an instrument with sufficient accuracy to ensure that the dew point is at least 2 K lower than the water inlet temperature.

4.4 Test procedure

4.4.1 Test set up

The test object shall be installed in the test room in accordance with the manufacturer's instructions (see Figure 1). Where the test ceiling is smaller than the test room then the infill panels between the test ceiling and the test room perimeter should be suitably air tight and thermally insulated to the requirements give in 4.2. The projection area of the test object shall be at least 70 % of the area of the test room surface, which can be expressed as follows:

$$R_i = \frac{A_i}{A_t} > 0,7 \qquad (1)$$

where

R_l is the installation area ratio;

A_l is the installation area;

and A_t is the test room area.

The active area ratio can also be calculated as follows:

$$R_a = \frac{A_s}{A_i} \qquad (2)$$

where

R_a is the active area ratio;

A_s is the active area;

and A_i is the installation area.

Where the installation details do not define the location of the test object on the total surface then the test object shall be centralised on the total surface, and if relevant the longest side of the test object shall be parallel to the longest side of the total surface. The void behind the surface containing the test object shall not exceed 300 mm.

Where water header pipework is not part of the standard installation and is particular to the test installation then this pipework shall be insulated with a maximum thermal conductivity of the surface of 4 $W/m^2 \cdot K$

The dummies are located in two rows, symmetrically along the longest centre-line of the room. The distance between the rows shall be half of the room width.

The distance between the centres of the dummies in each row shall be calculated from the following:

$$b = \frac{l_r}{n_r} \qquad (3)$$

where

b is the distance between the centres of the dummies in each row;

l_r is the room length;

and n_r is the number of dummies in the row.

The distance from the end walls to the centre of the nearest dummy shall be half the distance between dummies.

Typical examples are shown in Figures 3 and 4.

The properties of the dummies are specified in Figure 5.

NOTE In the case of a chilled floor the dummies are suitable for standing directly on the floor.

4.4.2 Steady state condition

Steady state conditions are considered to be obtained when the standard deviations of the recorded measurements are within the following limits for at least 60 minutes:

- reference temperature: 0,05 K;
- interior room surface temperatures: 0,5 K;
- mean water temperature 0,05 K;
- cooling water flow rate: 1 %.

In order to check steady state condition and stability of the measuring devices during the test period, the balance in the room in accordance with equation (4) shall be specified. Therefore, the heat flow through the walls, floor and ceiling shall be determined by means of preliminary calibration tests of the room or by calculation.

4.4.3 Measurements

Measurements shall be carried out in steady state conditions for each water flow rate with at least 3 different temperature differences ($\Delta\theta$); e.g. (6 ± 1) K, (8 ± 1) K, (10 ± 1) K.

At least one test series, as above, shall be carried out at the nominal water flow rate.

The reference room temperature shall be between 22 °C and 27 °C.

The cooling water inlet temperature shall be at least 2 K higher than the dew point temperature of the test room air.

The measurements for determining the cooling performance shall be carried out under steady state conditions.

The temperature of the test room's inner walls, floor and ceiling shall be controlled and maintained at the level necessary to ensure a maximum temperature difference between these surfaces and the reference room temperature of less than 1,0 K during the measurements.

The globe thermometer shall be placed in the centre of the room at a height of 1,1 m. In addition the room air temperature shall be measured in approximately the same position, but at a distance from the globe centre of 0,2 m.

The nominal cooling capacity of the test subject should be at least 35 Wm^{-2} at a temperature difference of 8 K.

The results of measurements should only be used when the heat balance for the test object, the dummies and the heat transfer through the test room's periphery does not deviate by more then 5 % of the total cooling capacity of the chilled surface, in accordance with equation (4).

$$\left|(P_B + P_S + P)\right| \leq 0{,}05\,P \tag{4}$$

4.4.4 Expression of results

The cooling capacity of the ceiling shall be calculated from the following equation:

$$P = c_p \cdot q_m\,(\theta_{w2} - \theta_{w1}) \tag{5}$$

The specific cooling capacity of ceiling cooling panels shall be calculated from the equation:

$$P_a = \frac{P}{A_a} \qquad (6)$$

The specific cooling capacity shall be plotted in a diagram as a function of the temperature difference between the globe temperature (reference room temperature) and the mean cooling water temperature. A curve of best fit shall be drawn through the plotted points. The curve shall be of the form:

$$P_a = k \cdot \Delta\theta^n \qquad \text{(see Figure 6)} \qquad (7)$$

where k is a characteristic constant
and n is the exponent

5 Uncertainty

5.1 Measurement

The uncertainty of each test is calculated according to the cumulative error law given in the following equation:

$$r = \sqrt{r_1^{\ 2} + r_2^{\ 2} + r_3^{\ 2}}$$

The maximum uncertainty of the individual measurements shall be as given in Table 2:

Table 2 – Uncertainty of measurements

Parameter	Tolerance	Uncertainty
Cooling water flow rate [q_w]	± 0,5 %	r_1 = 1 %
Cooling water temperature rise [θ_{w2} - θ_{w1}]	± 0,02 K	$r_2 \approx$ 2 % (at 2 K)
Temperature difference [$\Delta\theta$]	± 0,05 K	$r_3 \approx$ 1 % (at $\Delta\theta$= 8 K)

The total calculated uncertainty r shall be less than ± 3 % at nominal flow and a nominal temperature difference of 8 K.

5.2 Test room configuration

The test rooms permitted by this standard could amount to a further 3 % uncertainty from the test data, and hence the total, including test room, is approximately 4 %.

6 Test report

The test report shall include the following information:

a) name and address of the testing laboratory;

b) identification number of the test report;

c) name and address of the manufacturer or supplier of the test object;

d) name or identification codes for the test object;

e) detailed description of the test object including relevant materials, bonding techniques used and dimensions;

f) description of the installation of the test object(s) in the test room (open or closed ceiling etc.);

g) description and identification of the test equipment and instruments used;

h) test results for each measuring point (as described in 4.4.3 and 4.4.4);

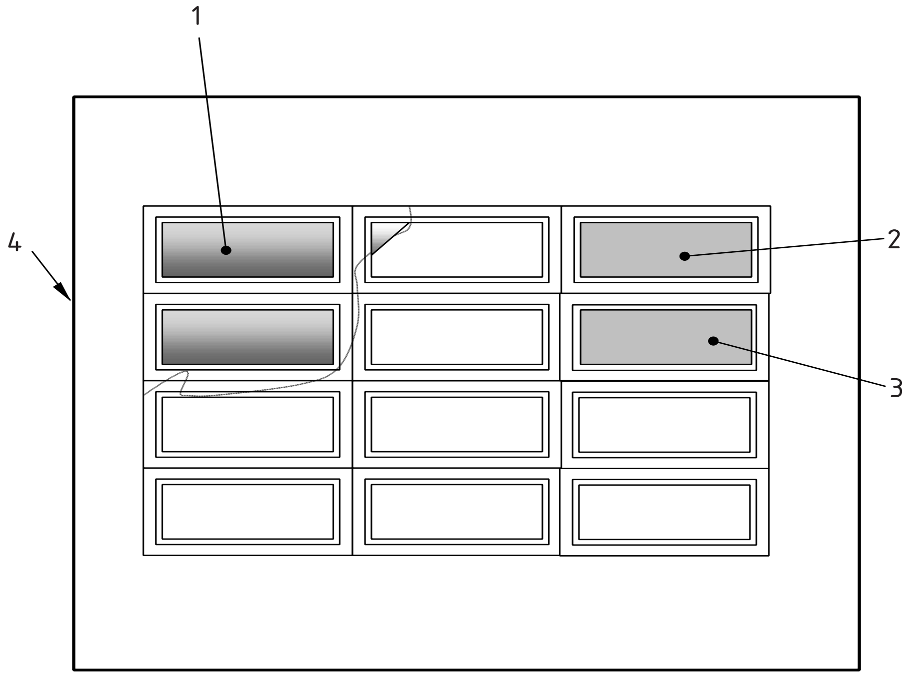
i) test results for each test series, including the constants k and n and diagrams (as described in 4.4.3 and 4.4.4);

j) a sample sheet of measurements and results (for information a typical example is given in Figure 6);

k) date and authorisation;

l) each page of the test report should give information of the total number of pages.

On each page a footnote that it is not permitted to copy single pages of the report.



Key

1 Total installation area A_i

2 Active area A_s

3 Panel area A_p

4 Test room area A_t

Figure 1 – Definitions of areas

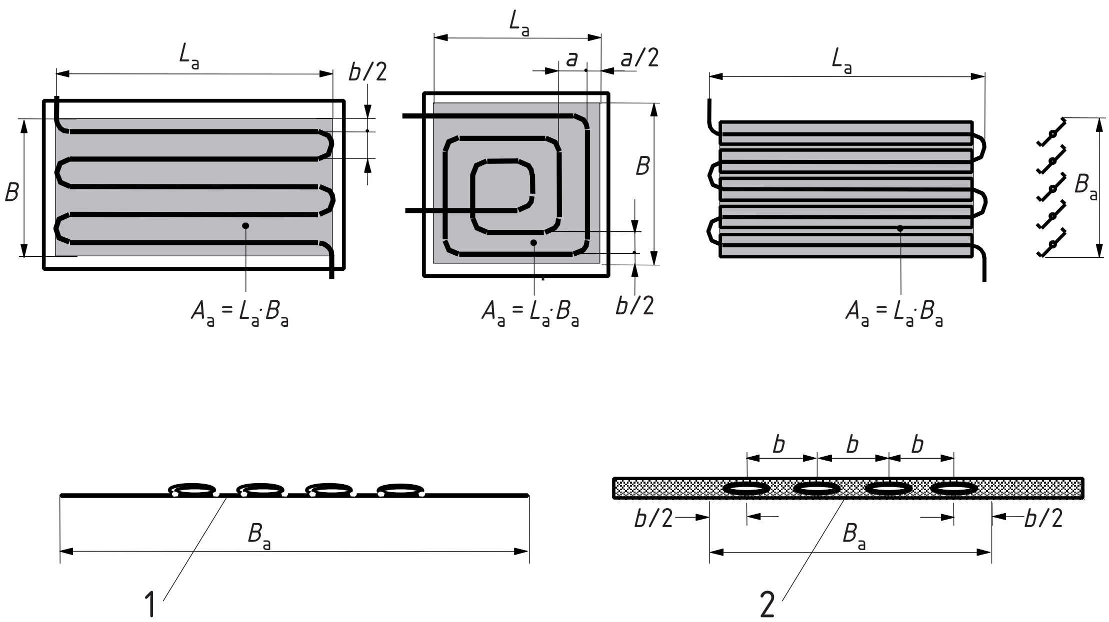
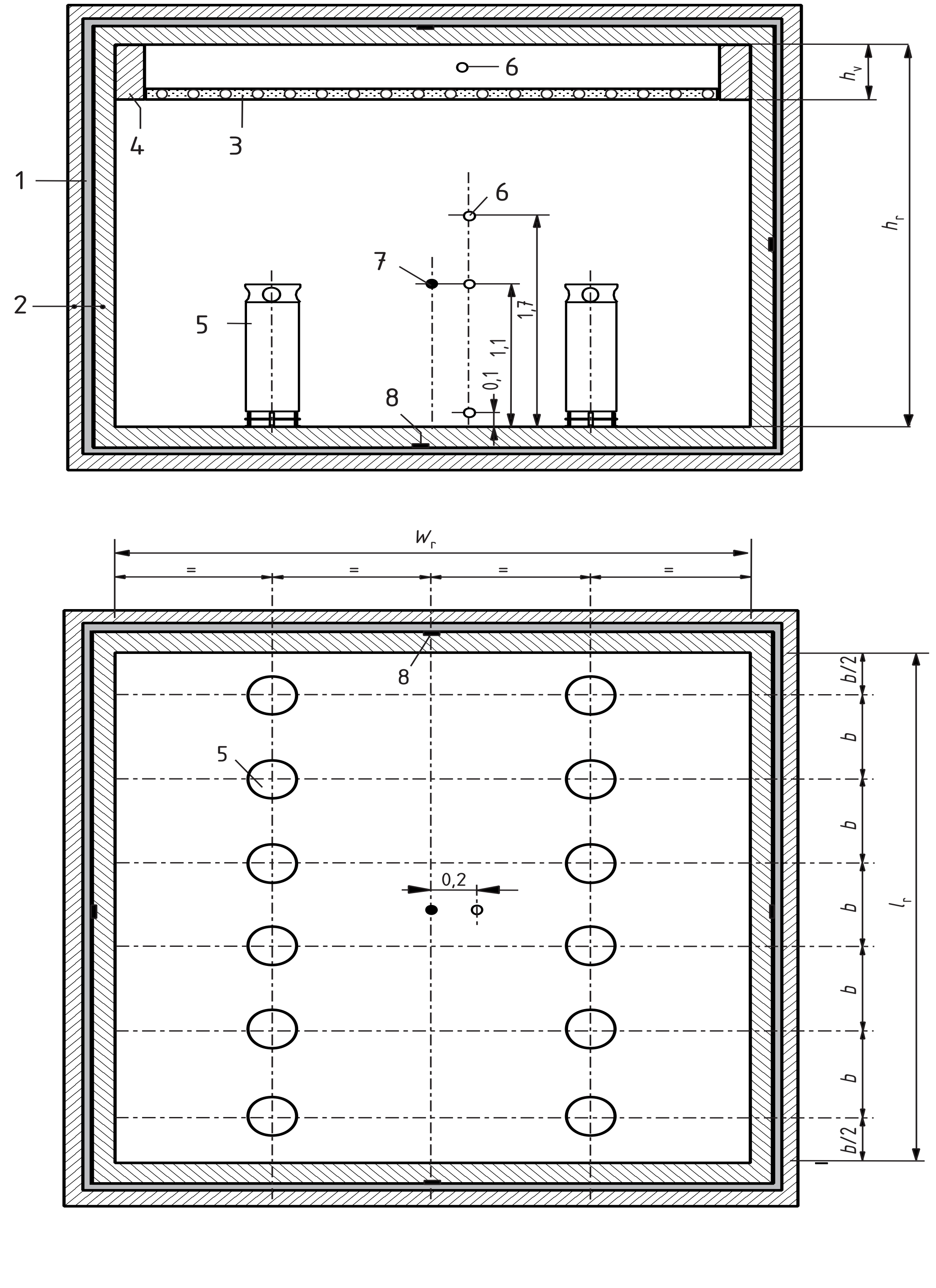


Figure 2 – Examples of active areas

Dimensions in metres

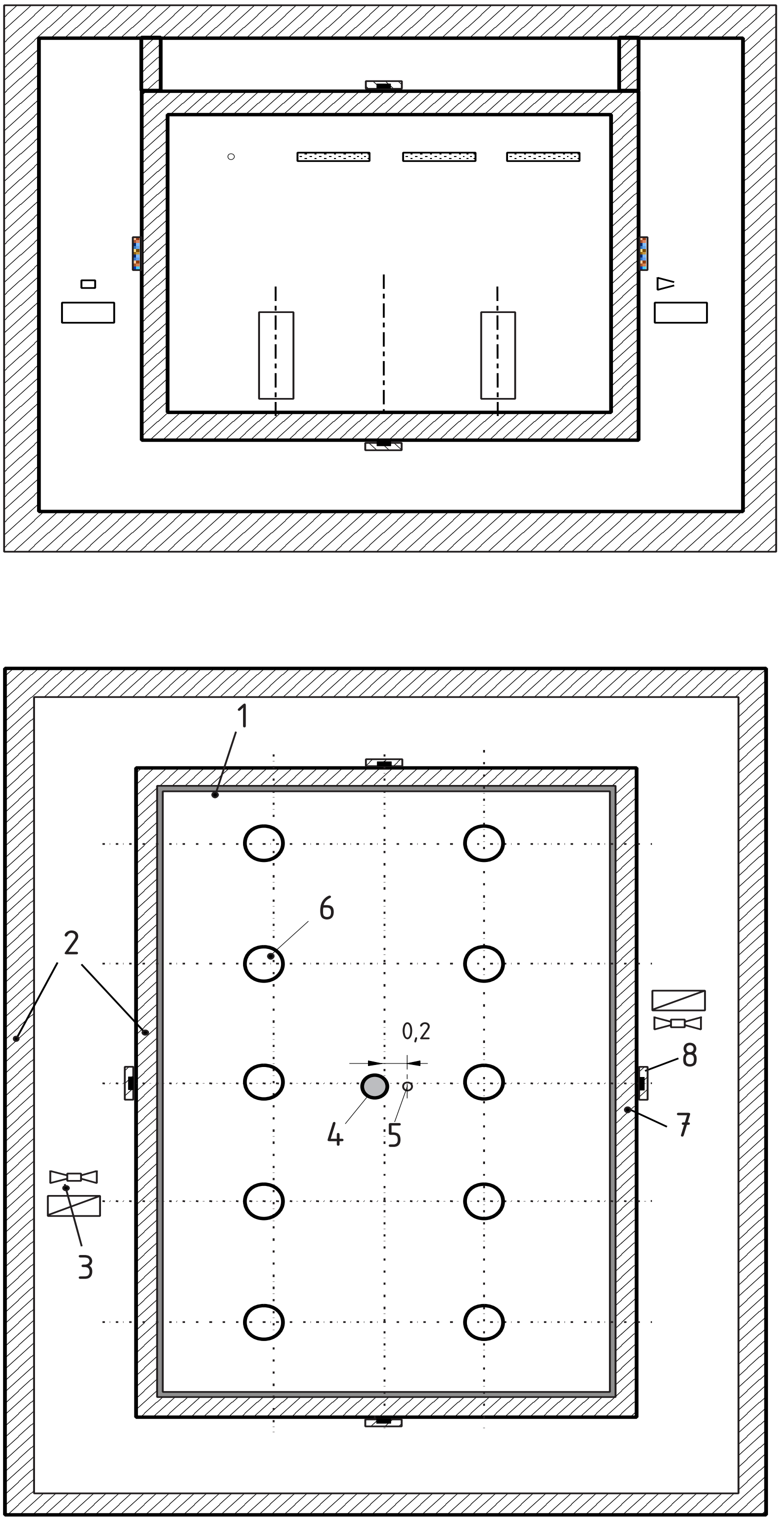


Key

1	Water-flowed metal plates	5	Cooling load simulator [dummy]
2	Thermal insulation	6	Measuring point of air temperature
3	Test specimen	7	Measuring point of Globe temperature
4	Edge insulation plate [essential for closed ceilings]	8	Measuring point of the temperature below the insulation

Figure 3 – Example of a test room (water controller boundary) with arrangement of a closed chilled ceiling, the dummies and the temperature measuring points

Dimensions in metres

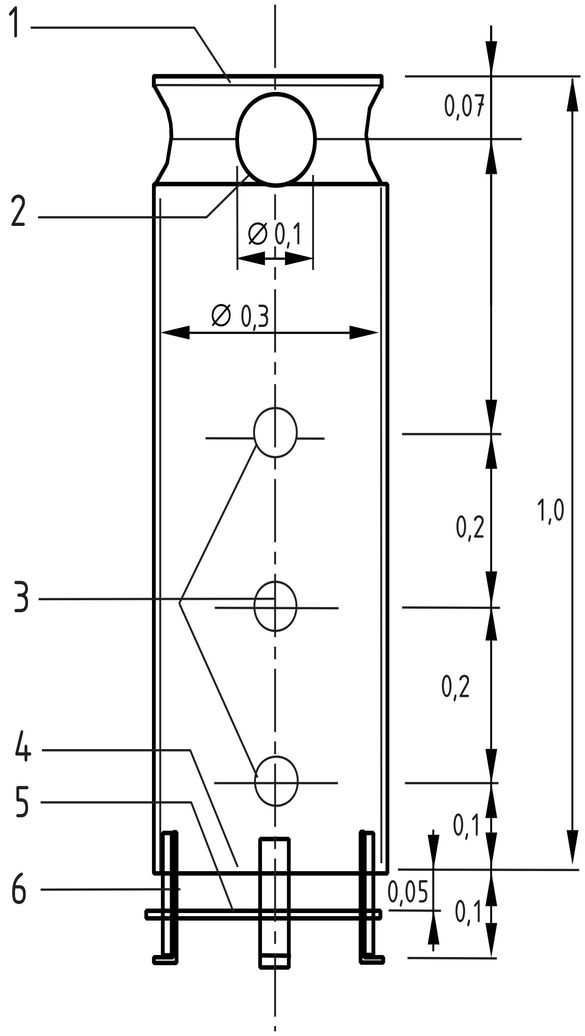


Key

1	Inner surface	5	Measuring point of Globe temperature
2	Thermal insulation	6	Cooling load simulator [dummy]
3	Fan and heat exchanger	7	Local thermal insulation
4	Measuring point of air temperature	8	Measuring point of the temperature below insulation

Figure 4 – Example of a test room (room within room) with arrangement of an open chilled ceiling, the dummies and the temperature measuring points

Dimensions in metres



Key

1 Cover

2 4 holes evenly distributed over the perimeter

3 3 lamps 60 W output per lamp

4 Without bottom

5 Bottom

6 3 feet distributed around the perimeter

Figure 5 – Cooling load simulator (dummy)

Example of Test Report Form and measurements

Description of product

Test object type –open/closed		Insulation	
Manufacturer		Water – connection of specimen	
Description of test object			
Description of measurement series		Manufacturer's comments	
Customer			

Reference areas			**Additional measurements of test room**		
Test room area [m^2]	A_t	14,44	Ceiling height [m]	h	2,30
Projection area [m^2]	A_i	12,16	Edge insulation [m]	s_1	0,10
Active area [m^2]	A_a	11,00	Edge insulation [m]	s_2	0,20

Results of measurements

Number of measuring point			1	2	3	4	5	6
Date of measurement			15-06	15-06	16-06			
Cooling water flow rate [kgh^{-1}]		q_w	538,7	545,3	543,4			
Temperatures [°C]	Water inlet	θ_{w1}	15,39	17,33	19,33			
	Water outlet	θ_{w2}	16,90	18,51	20,18			
	Globe	θ_g	26,42	26,07	25,73			
	Air – 1,7 m	$\theta_{a1,7}$	26,8	26,4	26,0			
	Air – 1,1 m	$\theta_{a1,1}$	26,9	26,4	26,0			
	Air – 0,1 m	$\theta_{a0,1}$	26,6	26,3	25,9			
	Surface wall 1	θ_{sw1}	25,8	25,8	25,8			
	Surface wall 2	θ_{sw2}	26,0	26,0	26,0			
	Surface wall 3	θ_{sw3}	25,7	25,7	25,7			
	Surface wall 4	θ_{sw4}	26,0	25,9	25,9			
	Surface inside floor	θ_{floor}	25,9	25,9	25,9			
	Surface inside ceiling	$\theta_{ceiling}$	25,9	25,9	25,9			
	Air-void	$\theta_{a\text{-}void}$	19,6	20,6	21,6			
Heating capacity – dummies [W]		P_s	927,9	717,9	518,1			

Calculations from measurements

Number of measuring point			1	2	3	4	5	6
Reference temperature [°C]		θ_{ref}	26,42	26,07	25,73			
$\Delta\theta$ [K]	Water temperature rise	$\Delta\theta_w$	1,52	1,18	0,85			
	Reference mean water	$\Delta\theta$	10,28	8,14	5,98			
Cooling capacity	Specific – Test room area [Wm^{-2}]	P_t	-65,8	-51,9	-37,3			
	Specific – projection area [Wm^{-2}]	P_i	-78,2	-61,6	-44,3			
	Specific – active area [Wm^{-2}]	P_a	-86,4	-68,1	-48,9			
	Total [W]	P	-950,9	-748,8	-538,3			
Heat transfer/test room periphery [W]		P_B	24,2	24,8	26,0			
Heat balance [W]		ΔQ	1,2	-6,1	5,8			
Heat balance maximum value [W]		$0,05\ P$	47,5	37,4	26,9			

Results at $\Delta\theta$ = 8 K		
Nominal capacity [Wm^{-2}]	P_a	66,6
Coefficient	k	7,489
Exponent	n	1,051

$$P_a = k \cdot \Delta\theta^{n}$$

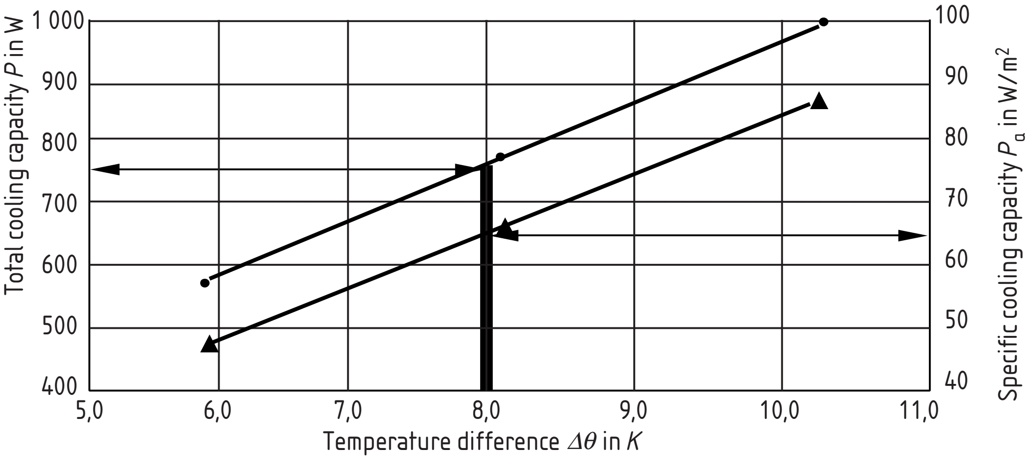


Figure 6 – Typical example of measurements and results

Annex A
(informative)

Guidance on the effects of Active Area Ratio

The typical effects of active area ratio R_a on performance are shown in Figure A.1,

where

$$\text{Active area ratio } R_a = \frac{A_a}{A_i} \bullet 100\ \%$$

and

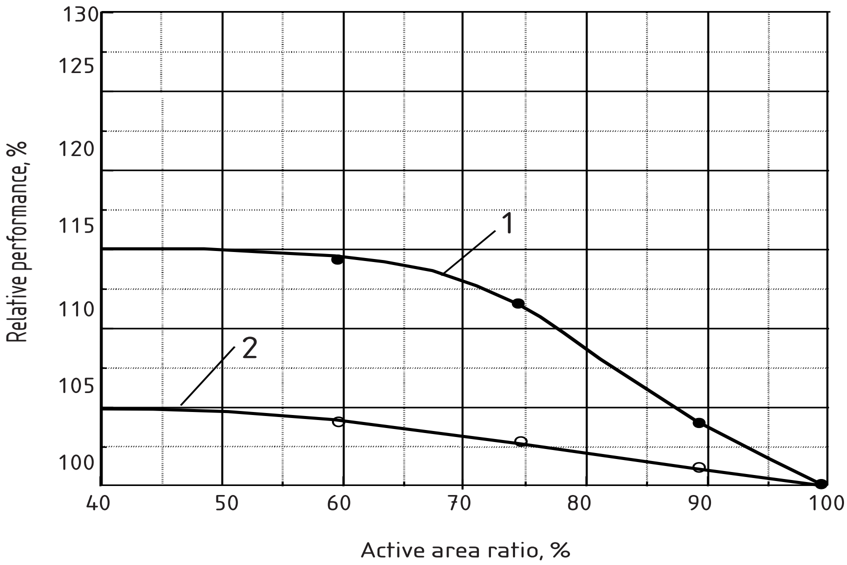
$$\text{Relative performance } = \frac{P(R_a)}{P(100)} \text{ in } \%$$

The results of the tests shall be reported in the form:

$P(85) = X$ W/m^2

where (85) is the percentage of the tested active area (R_a)

If R_a alters then further testing should be undertaken to define the effect.



Key

1 Chilled ceiling without thermal insulation

2 Chilled ceiling with thermal insulation

Figure A.1 – Effect of active area ratio on performance

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