Ventilation in buildings — Chilled beams — Testing and rating of active chilled beams

ICS 91.140.30,

British Standards

National foreword

This British Standard is the UK implementation of EN 15116:2008.

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 secretary.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2008

ISBN 978 0 580 59457 1

Amendments/corrigenda issued since publication

Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 15116

April 2008

ICS 91.140.30

English Version

Ventilation in buildings - Chilled beams - Testing and rating of active chilled beams

Ventilation des bâtiments - Poutres froides - Essai et évaluation des poutres froides actives

Lüftung von Gebäuden - Kühlbalken - Prüfung und Berechnung von aktiven Kühlbalken

This European Standard was approved by CEN on 28 February 2008.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 15116:2008: E

Contents

Foreword

This document (EN 15116:2008) 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of an identical text or by endorsement, at the latest by October 2008, and conflicting national standards shall be withdrawn at the latest by October 2008.

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1 Scope

This European Standard specifies methods for measuring the cooling capacity of chilled beams with forced air flow. The evaluation of aerodynamic air performance is not part of this standard. It will be dealt with in the future in a new standard entitled "Air terminal devices - Aerodynamic testing and rating for mixed flow applications for non isothermal testing - Cold jets".

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

The test method applies to all types of convector cooling systems with forced air supply using any medium as energy transport medium. This standard only applies to situations where induced air only passes through the heat exchanger (primary air does not pass through the heat exchanger).

NOTE The result is valid only for the specified test set up. For other conditions, (i.e. different positions of heat loads, inactive ceiling elements around the test objects), the producer should give guidance based on full scale tests.

This standard refers to water as the main cooling medium, with the possibility of additional cooling from the primary air. Wherever water is written, any other cooling medium can also be used in the test.

2 Normative references

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

EN 12792:2003, *Ventilation for buildings - Symbols, terminology and graphical symbols*

EN 14240:2004, *Ventilation for buildings — Chilled ceilings — Testing and rating*

EN ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 1: General principles and requirements (ISO 5167-1:2003)*

EN ISO 7726, *Ergonomics of the thermal environment - Instruments for measuring physical quantities (ISO 7726:1998)*

ISO 5221, *Air distribution and air diffusion - Rules to methods of measuring air flow rate in an air handling duct*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12792:2003 and the following apply.

3.1.1
active chilled beam
convector with integrated air supply where the induced air only passes through the cooling coil(s). The cooling medium in the coil is water

NOTE For the purpose of this standard primary air does not pass through the cooling coil.

3.1.2
test room
room in which the test object is mounted

3.1.3
primary air flow rate (q_p)
airflow supplied to the test object through a duct from outside of the test room or with primary air fan and ducting inside the test room

3.1.4
induced air flow rate (q_i)
secondary airflow from the test room induced into the test object by the primary air

3.1.5
exhaust air flow rate (q_e)
airflow discharged from the test room or return air if the primary air fan is located in the test room. The exhaust air flow rate is the same as the primary air flow rate

3.1.6
primary air pressure drop (Δp_a)
pressure drop across induction nozzle plus discharge loss

3.1.7
cooling water flow rate (q_w)
the average of the measured water flow rates during the test period

3.1.8
nominal cooling water flow rate (q_{wN})
flow rate that gives a cooling water temperature rise ($\theta_{w2} - \theta_{w1}$) of 2 K ± 0,2 K at nominal temperature difference ($\Delta\theta_N$ = 8 K) and at nominal air flow rate

3.1.9
water side pressure drop (Δp_w)
internal pressure drop across coil plus beam internal pipes

3.1.10
room air temperature (θ_a)
average of air temperatures measured with radiation shielded sensors in 1,1 m height in positions out of the main air current from the test object

3.1.11
globe temperature (θ_g)
temperature measured with a temperature sensor placed in the centre of the globe. The globe is placed in 1,1 m height in a position out of the main air current from the test object

3.1.12
reference air temperature (θ_r)
reference air temperature equals average air temperature of the induced air on the inlet side of the cooling coil(s), measured with radiation shielded sensors in three positions in the induced air opening, two centrally at the quarter points and one at the central point of the opening

3.1.13
cooling water inlet temperature (θ_{w1})
average of the measured water temperature into the test object during the test period

3.1.14
cooling water outlet temperature (θ_{w2})
average of the measured water temperature out of the test object during the test period

3.1.15
mean cooling water temperature (θ_w)
mean value of the cooling water inlet and outlet temperatures, [$\theta_w = 0{,}5 \cdot (\theta_{w1} + \theta_{w2})$]

3.1.16
primary air temperature (θ_p)
average of the primary air temperature during the test period

3.1.17
temperature difference ($\Delta\theta$)
difference between reference air temperature and mean cooling water temperature, $\Delta\theta = \theta_r - \theta_w$

3.1.18
nominal temperature difference ($\Delta\theta_N$)
nominal temperature difference (8 K) between the reference air temperature and the mean cooling water temperature ($\Delta\theta_N = \theta_r - \theta_w = 8$ K)

3.1.19
primary air temperature difference ($\Delta\theta_p$)
temperature difference between the reference air temperature and the primary air temperature

3.1.20
specific heat capacity (c_p)
heat required to raise the temperature of a unit mass of the cooling medium by 1K

NOTE c_p for water = 4,187 kJ·kg^{-1}·K^{-1} and c_p for air = 1,005 kJ·kg^{-1}·K^{-1}, at 15 °C.

3.1.21
cooling length (L)
active length of the cooling section

3.1.22
total length (L_t)
total installed length of the cooling section including casing

3.1.23
water side cooling capacity (P_w)
cooling capacity of the test object calculated from the measured cooling water flow rate and the cooling water temperature rise $P_w = c_p\, q_m\, (\theta_{w2} - \theta_{w1})$

3.1.24
primary air cooling capacity (P_a)
cooling capacity calculated from the primary air flow rate and primary air temperature difference $P_a = c_p\, q_p\, \rho_p\, (\theta_r - \theta_p)$

3.1.25
specific cooling capacity per unit length (P_L)
water side cooling capacity divided by the (active) cooling section length

3.1.26
specific cooling capacity (P_K)
cooling capacity divided by the difference between reference air temperature and mean cooling water temperature, $\Delta\theta = \theta_r - \theta_w$ raised to the exponent m i.e. $P_K = P_w / \Delta\theta^m$

3.1.27
nominal cooling capacity (P_N) or nominal specific cooling capacity (P_{LN})
water side cooling capacity calculated from the curve of best fit for the nominal cooling water flow rate at nominal temperature difference ($\Delta\theta_N$ = 8 K) and at nominal air flow rate

3.2 Symbols and units

For the purposes of this document the symbols given in EN 12792:2003 apply together with those given in Table 1.

Table 1 — Symbols and units

Symbol	Quantity	Unit
A	Constant in $P_K = Aq_p^n$	
At	Test room floor area	m^2
k_1	Constant in $P_w = k_1\ \Delta\theta^m$	
k_2	Constant in $P_w = k_2\ q_p^n$	
n	Exponent used in $P_K = Aq_p^n$	
m	Exponent used in $P_K = P_w/\Delta\theta^m$	
L	Cooling length (active length)	m
L_t	Total length of a chilled beam, including casing	m
c_p	Specific heat capacity	$kJ \cdot kg^{-1} \cdot K^{-1}$
h	Height from floor to underside of active chilled beam	m
P	Total cooling capacity $P = P_w + P_a$	W
P_L	Specific cooling capacity per unit active length	$W\ m^{-1}$
P_N	Nominal cooling capacity (at $\Delta\theta_N$ = 8 K)	W
P_{LN}	Nominal specific cooling capacity per unit active length (at $\Delta\theta_N$ = 8 K)	$W \cdot m^{-1}$
P_K	Specific cooling capacity ($P_K = P_w/\Delta\theta^m$)	$W\ K^{-m}$
P_a	Primary air cooling capacity	W
P_w	Water side cooling capacity	W
P_t	Specific cooling capacity per unit floor area	Wm^{-2}
P_s	Heating capacity of dummies	W
P_{TR}	Heat transfer test room periphery	W
q_w	Cooling medium flow rate	l(litre)$\cdot s^{-1}$
q_{wN}	Nominal cooling water flow rate	l(litre)$\cdot s^{-1}$
Δp_w	Water pressure drop	kPa
q_m	Cooling medium mass flow rate ($q_m = \rho_w\ q_w$)	$kg \cdot s^{-1}$
q_{pN}	Nominal primary air flow rate	l(litre)$\cdot\cdot s^{-1}$
q_p	Primary air flow rate	l(litre)$\cdot\cdot s^{-1}$
q_i	Induced air flow rate	l(litre)$\cdot\cdot s^{-1}$
q_e	Exhaust air flow rate (if appropriate)	l(litre)$\cdot\cdot s^{-1}$
Δp_a	Primary air pressure drop	Pa
θ_a	Room air temperature	°C
θ_e	Room exhaust air temperature (if appropriate)	°C
θ_g	Globe temperature	°C
θ_r	Reference air temperature	°C
θ_{sw}	Surface wall temperature	°C
θ_p	Primary air temperature	°C
θ_{w1}	Cooling water inlet temperature	°C
θ_{w2}	Cooling water outlet temperature	°C
θ_w	Mean cooling water temperature	°C
ρ_p	Density of primary air at θ_p	$kg \cdot m^{-3}$
ρ_w	Density of cooling medium at θ_w	$kg \cdot l^{-1}$(litre)
$\Delta\theta$	Temperature difference reference air temperature-water mean	K
$\Delta\theta_N$	Nominal temperature difference (=8K)	K
$\Delta\theta p$	Temperature difference reference air temperature -primary air temperature	K

4 Test method

4.1 Principle

4.1.1 General

The water side cooling capacity of the test object shall be determined from measurements of the cooling water flow rate and cooling water temperature rise under steady state condition. The water side cooling capacity shall be presented as a function of the primary air flow rate and the temperature difference between the reference air 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. Two alternative methods are allowed:

4.1.2 The internal heat supply method

The perimeter of the room shall be insulated and have negligible heat flow through it. The perimeters shall be insulated in such a way that during the test the average heat flow through these surfaces is less than 0,40 $W \cdot m^{-2}$.

To balance the cooling capacity of the test object, heating is supplied in the test room by means of a number of electric heated person simulators, dummies, as described in 4.3 of EN 14240:2004. The dummies are placed on the floor inside the test room. To get reproducible results the dummies shall be placed in determined positions as described in 4.4.1 of EN 14240:2004. For location of beam(s) relative to the dummies, see 4.4.1 of this standard.

NOTE This method uses the same test room and heating supply to the room as specified in EN 14240 for testing and rating of chilled ceilings.

4.1.3 The external heat supply method

To balance the cooling capacity of the test object, heating is supplied to the test room evenly distributed through the walls and the floor. The ceiling shall be insulated in such a way that during the test the heat flow through the ceiling is less than 0,40 $W \cdot m^{-2}$. The temperature of the inner walls and floor of the test room shall be controlled and maintained uniform at any level necessary to keep the desired room temperature. The maximum temperature difference between any point of the inner walls and floor during the test shall be less than 1 K.

4.2 Test room

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

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

NOTE 1 The test room specification enables the use of test rooms in accordance with EN 442 for the testing of chilled beams. 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 outside of the room or outer room as appropriate should be insulated. The heat loss to the outside should be determined by preliminary calibration (without test object cooling) to demonstrate compliance with either 4.1.2 or 4.1.3 as appropriate.

It is recommended that fixed temperature sensors should be installed at least in the centre of each inside wall and floor.

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

The inner wall and floor temperatures can be controlled by different methods for instance.

a) Water panels covering all outside surfaces with circulating temperature controlled water.

b) Forced air flow circulation, temperature controlled with electric heaters or heated water panels, in an exterior room.

NOTE 2 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.

The primary air is ducted to the test object through an insulated duct from the outside of the test room. The exhaust opening shall be placed in the ceiling or in a wall near the ceiling in a place outside the main total air current from the test object.

Another acceptable alternative is to take air from inside the test room by using a fan inside the test room having therefore a full recirculatory system which will simplify the heat balance checks. However in this case the fan power has to be considered as part of the load. The fan inlet duct should be placed near the ceiling but outside of the main air current from the test object.

4.3 Instrumentation

4.3.1 The internal heat supply method

To balance the cooling of the test object (and the cooling from the primary air in the non-isothermal tests), heating is supplied in the test room by means of a number of electric heated person simulators, dummies, placed on the floor inside the test room as described in EN 14240. The effective electric power to the dummies shall be measured over the test period with watt-meter plus calibrated timer or an integrating watt-hour meter with an uncertainty of 1 % or less.

4.3.2 The external heat supply method

To balance the cooling of the test object (and the cooling from the primary air in the non-isothermal tests), heating is supplied into the test room evenly distributed over the walls and floor by means of one of the following methods:

a) water panels with circulating warm water. The heat supplied should be determined from measurements of the water flow rate and water temperature difference for the actual panels. (To get sufficient temperature difference this can be measured in a primary circuit feeding water to the panels).

b) a number of electric heating elements placed in the outer room that covers all walls and the floor of the inside test room. It is recommended to use fans for forced air circulation in the outer room. The effective electric power to the heating elements and circulation fans shall be measured over the test period with watt-meter plus calibrated timer or an integrating watt-hour meter with an uncertainty of 1 % or less.

4.3.3 Other instrumentation

Air temperatures shall be measured by radiant shielded sensors with an uncertainty equal to ± 0,2 K or less.

Surface temperatures shall be measured by sensors fixed to small metal plates glued to the surface and painted to get as high emission rate as the surface, or with other types of surface temperature sensors, with an uncertainty of 0,2 K (= ± 0,1 K) or less.

Globe temperature shall be measured with a sensor calibrated to give an uncertainty of 0,2 K (= ± 0,1 K) or less, placed in the centre of a black globe with diameter 60 - 150 mm, according to EN 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, calibrated with an uncertainty of 0,2 K (= ± 0,1 K) or less. Where temperature differences are required pairs of sensors shall be calibrated to give an uncertainty of the cooling water temperature rise (θ_{w2} - θ_{w1}) of ± 0,02 K or less. The reference air temperature sensor shall be calibrated together with the water temperature probes to give an uncertainty of measurement of the temperature difference between the reference air temperature and the inlet and outlet water temperatures of ± 0,02 K or less.

The water flow rate through the test object shall be measured with a flow meter calibrated to an uncertainty of 1 % (= ± 0,5 %) or less, (i.e. by a weighing method). In any calibration method that removes water from the system care shall be taken to avoid air entering the system or adequate means shall be provided for its removal. The c_p of the water is affected by the presence of air.

The primary air flow rate to the test object shall be measured using instruments in accordance with EN ISO 5167 or ISO 5221 with an uncertainty of ± 3 % or less.

The dew point of the test room air shall be measured with an instrument that has 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

To avoid different thermal performance with the two test method principles, the test object shall always be tested free hanging. If the test object is intended for recessed mounting, a part of a false ceiling shall be mounted around the test object. This part of false ceiling shall be 300 mm wide boards adjacent to the chilled beam to provide suitable surface to control flow to horizontal discharge. The discharge direction shall be determined with smoke tests for all air flow rates tested.

The test object shall be installed symmetrically about the centre of the ceiling and with the longest side parallel to the longest room side and parallel to the two rows of dummies. The minimum distance between walls and the shortest sides of the beam shall be 200 mm. The height from the top of the beam to the ceiling shall be 100 mm - 300 mm if the induced air enters the beam from above.

If more than one test object is needed to comply with 4.4.3, because of the minimum capacity, they should be connected in series in a single line format. The test report shall describe how the objects are connected. Connecting pipes or tubes which are not part of the standard installations shall be insulated with a maximum thermal conductivity of 4 $W/m^2 \cdot K$.

If there is concern about any possible direct recirculation taking place between beam discharge and room air induction then flow visualisation should be undertaken using for example smoke or other means to qualify this. The results of this flow visualisation shall be reported.

4.4.2 Steady state condition

Steady state conditions are considered to have been obtained when the standard deviations of the recorded measurements (sampling rate approximately 1 per min) are within the following limits for at least 60 min:

Reference temperature: 0,05 K

Interior room surface temperatures:	0,5 K
Mean water temperature:	0,05 K
Cooling water flow rate:	1 % of nominal
Primary air temperature:	0,2 K
Primary air flow rate:	1,5 %

4.4.3 Measurements

The measurements shall be carried out in steady state conditions with at least three different $\Delta\theta$ = (6, 8, 10 K) ± 1 K, driving the test sample with the nominal primary air flow rate, according to the manufacturers recommendations. Varying the primary air flow rate at nominal $\Delta\theta$ = 8 K, q_p= (0,8 × q_{pN} , q_{pN} , 1,2 × q_{pN}) ± 5 %, will determine the influence of primary air on thermal performance. These tests are necessary for each water flow rate.

The water flow rate shall be kept constant in each test series. At least two test series shall be carried out, with different water flow rates. One test series shall be carried out with the nominal flow rate (q_{wN}). One other test series should be carried out with half of the nominal water flow rate.

NOTE 1 After steady state conditions have been demonstrated for a period of 60 min, retrospectively the results during this period can be used for performance evaluation.

NOTE 2 If the primary air fan is mounted outside the test room it is recommended to measure both primary supply air flow rate and exhaust air flow rate simultaneously as a check on test room leakage. This data should be included in the standard test sheets.

NOTE 3 Test room pressure during the tests should be measured and reported.

NOTE 4 If information is required on water flow rates intermediate or outside the range of those tested, further tests with these new water flow rates should be undertaken as the relationship of performance with water flow rate is not linear.

Primary air temperature is not a critical parameter and therefore the manufacturers recommended values shall be used and reported.

A sample measurement sheet is shown in Figure 1.

The reference air temperature (θ_r) shall be between 22 °C and 27 °C.

The cooling water inlet temperature (θ_{w1}) shall be at least 2 K higher than the dew point of the test room air (θ_a) to avoid heat exchanger condensation.

The measurements are carried out with at least twenty recordings under steady state conditions.

For the internal heat supply method the temperature of the test room's inner walls, floor and ceiling shall be controlled and maintained uniform at any level necessary to maintain a maximum temperature difference between these surfaces and the reference air temperature of less than 1 K during the measurements.

For the external heat supply method the temperature of the inner walls and floor of the test room shall be controlled and maintained uniform at any level necessary to keep the desired reference air temperature. The maximum temperature difference between any point of the inner walls and floor during the test shall be less than 1 K.

The globe temperature shall be measured in 1,1 m height in one position near the centre of the room, but outside the cool current from the test object (position to be determined by smoke). In addition the room air temperature (θ_a) might 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 object shall be at least 15 W/m^2 floor area.

NOTE 5 Heat balance can be used to check reliability of results similar to procedures in EN 14240. The total heat input to the test room should be equal to the cooling capacity of the beam, calculated as explained in 4.4.4, plus the cooling capacity of the primary air ($P_{air} = q_p \cdot \rho_p \cdot c_p \cdot \Delta\theta_p$).

The relative humidity of the air in the test room should be determined.

The condition of the water cooling coils during the tests with respect to condensation should be noted i.e. dry, moist or dripping.

4.4.4 Expression of results

The cooling capacity of the primary air shall be calculated from the equation:

$$P_a = q_p \ \rho_p \ c_p \ \Delta\theta_p$$

The water side cooling capacity of the beam(s) shall be calculated from the equation:

$$P_w = c_p \ q_m \ (\theta_{w2} - \theta_{w1})$$

Figure 2 shows a typical calculation sheet.

The cooling capacity shall be plotted in diagrams as functions of the temperature difference $\Delta\theta$ and the primary air flow rate. Curves of best fit shall be drawn through the plotted points. The curves are expected to be of the form:

$$P_w = k_1 \Delta\theta^m \text{ or } P_w = k_2 q_p^{n2}$$

or:

$$P_K = P_w / \Delta\theta^m = A q_p^n \quad \text{(see Figure 2)}$$

k_1, k_2 and A are characteristic constants

m and *n* are the exponents

for the product under test

From this curve of best fit the nominal cooling capacity P_N (at $\Delta\theta_N$ = 8 K) shall be calculated and reported.

The single test points shall be plotted in the same diagram and the deviation from the actual curve of best fit shall be calculated in % of the cooling capacity at the same $\Delta\theta$ (See Figure 2).

In addition a diagram showing the cooling capacity as a function of the temperature difference between the globe temperature or room air temperature and the mean water temperature may be plotted as additional information.

5 Uncertainty

The uncertainty of each test is calculated according to the cumulative error law:

$$r = \sqrt{r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2}$$

The maximum uncertainty of the individual measurements shall be:

Cooling water flow rate (q_w):	± 1,5 %	$r_1 = 3$ %
Cooling water temperature rise ($\theta_{w2} - \theta_{w1}$):	± 0,02 K	$r_2 \approx 2$ % (at 2 K)
Temperature difference ($\Delta\theta$):	± 0,1K	$r_3 \approx 2{,}5$ % (at $\Delta\theta = 8$ K)
Primary air flow rate (q_p)	± 1,5 %	$r_4 \approx 3$ % *
Test room configuration (internal/external heat sources)		$r_5 \approx 3$ %

*± 3 % uncertainty of flow rate has an indirect influence on performance. This is estimated as the square root of the flow uncertainty.

Total calculated uncertainty *r* shall be less than ± 6 % at nominal flow and $\Delta\theta$=8 K.

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 of the test object.

e) Detailed description of the test object including relevant materials and dimensions (including coil cooling length, inside pipe diameter, number of pipe rows and fin spacing).

f) Description of the installation of the test object(s) in the test room (including clearance above beam to roof of test room).

g) Description and identification of the test equipment and instruments used.

h) Test results for each measuring point (as described in 4.4.4) and including primary air and water side pressure drop.

i) Test results for each test series, including the constants and diagrams (as described in 4.4.4).

j) Nominal capacities.

k) Sketches of air flow pattern direction near the test object, drawn from smoke tests.

l) A sample sheet of measurements and results.

m) Date and authorisation.

n) Each page of the test report shall have a page number and the total number of pages.

o) It is recommended that there is on each page a footnote that it is not allowed to copy single pages of the report.

Description - Measurement			
test object – type		insulation	
manufacturer		water – connection of specimen	
description test object		manufacturer - comments	
description measuring series			
customer			

Results of Measurements												
			A – Nominal water flow rate q_{wN}					**B – 0,5 × Nominal water flow rate q_{wN}**				
Test-series			**nominal primary air q_p**			**vary q_p**		**nominal primary air q_p**			**vary q_p**	
Test No			1	2	3	4	5	6	7	8	9	10
Date			15.06.02	15.06.02	15.06.02	16.06.02	20.06.02	16.06.02	20.06.02	20.06.02	20.06.02	20.06.03
primary air flow rate – l/s		q_p	53,5	53,5	53,5	42,8	64,2	53,5	53,5	53,5	42,8	64,2
cooling water flow rate – l/s		q_w	0,1496	0,1515	0,1509	0,1515	0,1515	0,0748	0,0748	0,0748	0,0748	0,0748
temperatures	water inlet - °C	θ_{w1}	15,39	17,33	19,33	17,33	17,33	19,04	14,89	16,89	16,74	16,56
	water outlet - °C	θ_{w2}	16,90	18,51	20,18	18,33	18,68	20,55	17,55	19,03	18,54	19,01
	primary air - °C	θp	20,75	20,73	20,65	20,73	20,73	20,67	20,75	20,73	20,65	20,65
	globe – 1,1 m - °C	θ_g	26,42	26,07	25,73	26,07	26,07	25,73	26,42	26,07	25,73	25,73
	reference - °C	θ_r	26,83	26,42	25,99	26,42	26,42	25,99	26,83	26,42	25,99	25,99
	air – 1,7 m - °C	$\theta_{a1.7}$	26,83	26,42	25,99	26,42	26,42	25,99	26,83	26,42	25,99	25,99
	air – 1,1 m - °C	$\theta_{a1.1}$	26,85	26,45	26,01	26,45	26,45	26,01	26,85	26,45	26,01	26,01
	air – 0,1 - °C	$\theta_{a0.1}$	26,65	26,31	25,89	26,31	26,31	25,89	26,65	26,31	25,89	25,89
	surface wall 1 - °C	θ_{sw1}	25,84	25,81	25,83	25,81	25,81	25,83	25,84	25,81	25,83	25,83
	surface wall 2 - °C	θ_{sw2}	25,98	25,97	25,97	25,97	25,97	25,97	25,98	25,97	25,97	25,97
	surface wall 3 - °C	θ_{sw3}	25,69	25,68	25,68	25,68	25,68	25,68	25,69	25,68	25,68	25,68
	surface wall 4 - °C	θ_{sw4}	25,96	25,95	25,94	25,95	25,95	25,94	25,96	25,95	25,94	25,94
	surface inside floor - °C	θ_{sw5}	25,91	25,89	25,89	25,89	25,89	25,89	25,91	25,89	25,89	25,89
	surface inside ceiling - °C	θ_{sw6}	25,93	25,93	25,94	25,93	25,93	25,94	25,93	25,93	25,94	25,94
	air void	$\theta_{a\text{-}void}$	19,55	20,55	21,65	20,55	20,55	21,65	19,55	20,55	21,65	21,65
healing capacity – dummies-W		P_s	1 376,3	1 148,2	867,8	963,5	1 325,9	793,8	1 230,3	1 067,5	834,6	1 191,3

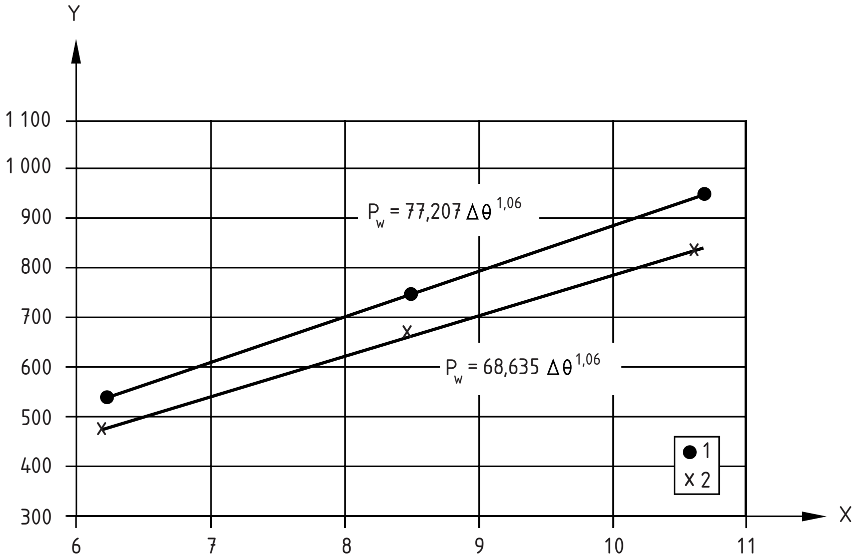
Reference		
testroom area	At	14,44 m^2
total length	L_t	2,80 m
cooling length	L	2,56 m

Dimensions		
mounting	h	2,30 m

Figure 1 — Typical example of measurements

Calculations on measurement												
			A – Nominal water flow rate				**B – 0,5 x Nominal water flow rate**					
	Test - series		**Nominal primary air q_p**		**Vary q_p**		**Nominal primary air q_p**			**Vary q_p**		
	Test No		1	2	3	4	5	6	7	8	9	10
	Date		15.06.02	15.06.02	15.06.02	16.06.02	20.06.02	16.06.02	20.06.02	20.06.02	20.06.02	20.06.02
	reference temperature - °C	θ_r	26,83	26,42	25,99	26,42	26,42	25,99	26,83	26,42	25,99	25,99
temp differences	water temperature rise - K	$\theta_{w2}-\theta_{w1}$	1,52	1,18	0,85	0,99	1,35	1,51	2,66	2,14	1,80	2,45
	reference-water mean - K	$\Delta\theta$	10,69	8,50	6,24	8,59	8,42	6,20	10,61	8,46	8,35	8,21
	reference-primary air - K	$\Delta\theta_p$	6,08	5,69	5,34	5,69	5,69	5,32	6,08	5,69	5,34	8,21
cooling capacity	specific; testroom area – W m^{-2}	P_t	-65,8	-51,8	-37,2	-43,6	-59,0	-32,7	-57,6	-46,3	-39,0	-53,1
	specific; active length – W m^{-1}	P_L	-371,1	-292,1	-209,8	-245,7	-332,8	-184,3	-325,2	-261,4	-219,9	-299,3
	specific; total length – W m^{-1}	P_{Lt}	-339,3	-267,0	-191,8	-224,7	-304,3	-168,5	-297,3	-239,0	201,1	-273,7
	air – W	P_a	-388,5	-364,1	-342,0	-291,3	-437,0	-340,7	-388,5	-364,1	-273,6	-410,4
	water - W	P_w	-950,1	-747,7	-537,2	-629,1	-851,9	-471,9	-832,4	-669,2	-563,0	-766,2
	heat transfer test room periphery -W	P_{TR}	-25,1	-14,6	-2,4	-14,6	-14,6	-2,4	-25,1	-14,6	-2,4	-2,4
	heat balance - W	ΔQ	12,5	21,8	-13,7	28,5	22,4	-21,1	-15,8	19,5	-4,3	12,3
	heat balance max – value - W	0,05 P	47,5	37,4	26,9	31,5	42,6	23,6	41,6	33,5	28,1	38,3

Figure 2 — Typical example of measurements and calculations



Key

Y = waterside cooling capacity P_w in W

X = reference air temperature – Mean water temperature $\Delta\theta$ in K

1 = nominal water flow rate

2 = 0,5 x nominal water flow rate

Result of measurement			
nominal water flow rate	nominal capacity - W	P_N	698,6
	nominal capacity - W/m	P_{LN}	272,9
	coefficient	A	3,1583
	exponent	n	0,8028
		m	1,06
0,5 x nominal water flow rate	nominal capacity - W	P_N	639,1
	nominal capacity - W/m	P_{LN}	249,7
	coefficient	A	2,8928
	exponent	n	0,8025
		m	1,06

$P_N = Aq_p^{\,n}\,\Delta\theta^m$

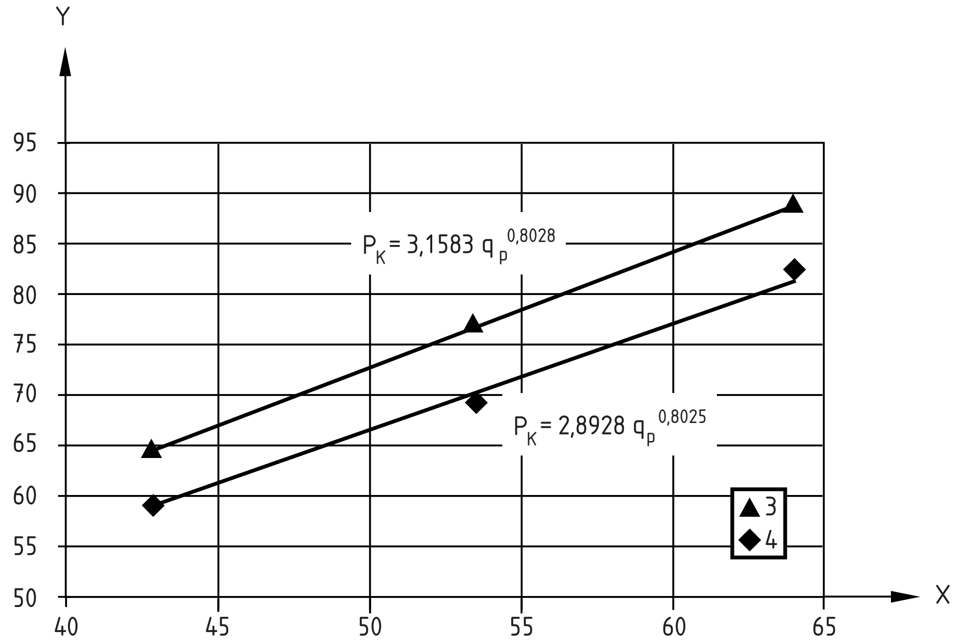
nominal capacity at: $\Delta\theta = 8K$

$q_{pN} = 53{,}5\ l\ s^{-1}$

$q_{wN} = 0{,}150\ l\ s^{-1}$

$q_{wN\ x\ 0,5} = 0{,}075\ l\ s^{-1}$

Figure 3 — Typical example of results



Key

Y = specific cooling capacity P_k W K^{-m}

X = primary air flow rate q_p l(litre) s^{-1}

3 = nominal water flow rate

4 = 0,5 x nominal water flow rate

Figure 4 — Typical example of results (continued)

Bibliography

[1] EN 13182, *Ventilation for buildings — Instrumentation requirements for air velocity measurements in ventilated spaces*

[2] EN 14518, *Ventilation for buildings — Chilled beams — Testing and rating of passive chilled beams*

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