Ventilation for buildings — Chilled beams — Testing and rating of passive chilled beams

The European Standard EN 14518:2005 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 14518:2005.

The UK participation in its preparation was entrusted to Technical Committee RHE/2, Ventilation for buildings, heating and hot water services, 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 UK interests informed;
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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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

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Foreword

This European Standard (EN 14518:2005) 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of an identical text or by endorsement, at the latest by December 2005, and conflicting national standards shall be withdrawn at the latest by December 2005.The other standards dealing with chilled beams and chilled ceilings are:

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

prEN 15116 *Ventilation in buildings — Chilled beams — Testing and rating of active chilled beams*

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1 Scope

This European Standard specifies test conditions and methods for the determination of the cooling capacity of chilled beams or other similar systems with free convection, i.e. without forced air flow. Also included is the method to determine local air velocity and temperature below the beam.

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

The test method applies to all types of convector 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, inactive ceiling elements around the test objects or forced flow into or around the test object), the producer should give guidance based on full scale tests.

This standard refers to water as the cooling medium throughout, however, wherever water is written, 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.

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 13182, *Ventilation for buildings — Instrumentation requirements for air velocity measurements in ventilated spaces*

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

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

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
chilled beam
convector cooled with water and mounted under the ceiling of the test room with suspended ceiling

NOTE This standard deals with passive beams, i.e. convectors with free convection only.

3.1.2
test room
room in which the test object is mounted

3.1.3
convection flow
local airflow from a heating element in the test room, or the local airflow from a test object of type chilled beam

NOTE These types of convection flow can be visualised with smoke tests.

3.1.4
room air temperature (θ_a)
average of air temperatures measured with radiation shielded sensors in positions out of the convection flow

3.1.5
globe temperature (θ_g)
temperature measured with a temperature sensor placed in the centre of the globe. The globe is placed in a position out of the convection flow

3.1.6
air on coil temperature (θ_{ac})
reference temperature equals average air temperature on the inlet side of a cooling convector, measured with radiation shielded sensors in two positions along the convector, ¼ of the convector length from each end of the convector. One sensor is placed 30 mm vertically above the left side and the other 30 mm above the right side of the convector

3.1.7
local air temperature
temperature measured at 0,75 m below the beam discharge point in the convective airflow from the beam

3.1.8
local mean air velocity
velocity measured at 0,75 m below the beam discharge point in the convective airflow from the beam

3.1.9
cooling water flow rate (q_v)
average of the measured water flow rates during the test period

3.1.10
cooling water inlet temperature (θ_{w1})
average of the measured water temperature into the test object during the test period

3.1.11
cooling water outlet temperature (θ_{w2})
average of the measured water temperature out of the test object during the test period

3.1.12
mean cooling water temperature (θ_w)
mean value of the cooling water inlet and outlet temperatures, ($\theta_w = 0{,}5 \cdot [\theta_{w1} + \theta_{w2}]$)

3.1.13
temperature difference (Δθ)
difference between air on coil temperature and mean cooling water temperature, ($\Delta\theta = \theta_{ac} - \theta_w$)

3.1.14
specific heat capacity (c_p)
heat require to raise the temperature of unit mass of the cooling medium by I K

NOTE c_p for water = 4,187 kJ/(kg·K) at 15 °C.

3.1.15
cooling length (L) of a chilled beam
active length of the cooling section

3.1.16
total length (L_t) of a chilled beam
total installed length of the cooling section including casing

3.1.17
cooling capacity (P)
total cooling capacity of the test object calculated from the measured cooling water mass flow rate and the cooling water temperature rise

3.1.18
specific cooling capacity of a chilled beam (P_L)
cooling capacity divided by the (active) cooling length

3.1.19
nominal temperature difference
nominal temperature difference (8 K) between the air on coil temperature and the mean cooling water temperature ($\Delta\theta_N = \theta_{ac} - \theta_w = 8$ K)

3.1.20
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 the nominal temperature difference ($\Delta\theta_N = 8$ K)

3.1.21
nominal cooling capacity (P_N) or nominal specific cooling capacity (P_{LN})
cooling capacity calculated from the curve of best fit for the nominal cooling water flow rate at the nominal temperature difference ($\Delta\theta_N = 8$ K)

3.2 Symbols and units

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

Table 1 — Symbols and units

Symbol	Quantity	Unit
c_p	Specific heat capacity	KJ/(kg·K)
L	Active length of a chilled beam	m
L_t	Total length of a chilled beam, including casing	m
P	Total cooling capacity $P = c_p \cdot q_m \cdot (\theta_{w2} - \theta_{w1})$	W
P_L	Specific cooling capacity of a chilled beam, relative to active length L	W/m
P_N	Nominal cooling capacity at $\Delta\theta_N = \theta_{ac} - \theta_w = 8$ K	W
P_{LN}	Nominal specific cooling capacity at $\Delta\theta_N = 8$ K	W/m
P_{Lt}	Specific cooling capacity of a chilled beam, relative to total length L_t	W/m
q_v	Cooling medium volume flow rate	l/s
q_{vN}	Nominal cooling water volume flow rate	l/s
q_m	Cooling medium mass flow rate ($q_m = \rho_w \cdot q_v$)	kg/s
v_L	Local mean air velocity at 0,75 m below the beam discharge plane	m/s
ρ_w	Density of cooling medium at θ_w	kg/l
θ_a	Room air temperature	°C
θ_g	Globe temperature	°C
θ_{ac}	Reference temperature = air on coil temperature	°C
θ_L	Local air temperature at 0,75 m below the beam discharge plane	°C
$\Delta\theta$	Temperature difference	K
$\Delta\theta_N$	Nominal temperature difference (8 K)	K
θ_{w1}	Cooling water inlet temperature	°C
θ_{w2}	Cooling water outlet temperature	°C
θ_w	Mean cooling water temperature	°C

4 Test method

4.1 Principle

4.1.1 General

The 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 cooling capacity shall be presented as a function of the temperature difference between the reference air on coil temperature and the mean cooling water temperature.

Local air temperature and local mean air velocity shall be measured in the convective discharge from the beam at 0,75 m below the beam discharge plane.

The measurements shall be performed in an airtight room with controlled temperatures on the inside surfaces. Two alternative methods are allowed:

4.1.2 The internal heat supply method

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.

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/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 4.3.1. The dummies are placed on the floor inside the test room. To get reproducible results it is essential that the dummies 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.

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/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 outside the direct convective down flow from the beam during the test shall be less than 1,0 K.

4.2 Test room

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

The ratio width to length shall not be 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 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 allowed that the test room dimensions deviate from the recommended dimensions.

The test room shall be sufficiently tight to minimise any flow from the ambient air outside, which shall not exceed 0,8 l/s/m^2 of the perimeter surface at a pressure difference of 50 Pa. The air within the test room shall not be influenced by any forced airflow.

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 surface.

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

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 or heated water panels, in an exterior room.

4.3 Instrumentation

4.3.1 The internal heat supply method

To balance the cooling of the test object, 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. Note the centre line of the test beam should be parallel to the 2 rows of dummies. The effective electric power to the dummies shall be measured with a watt-meter of quality class 1,0 or better.

4.3.2 The external heat supply method

To balance the cooling of the test object, 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 obtain 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 with watt-meter of quality class 1,0 or better.

4.3.3 Other instrumentation

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

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 accuracy better than 0,2 K (= ± 0,1 K).

Globe temperature shall be measured with a sensor with accuracy better than 0,2 K (= ± 0,1 K), placed in the centre of a black globe with diameter 60 mm - 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, with an accuracy better than 0,2 K (= ± 0,1 K). The sensors shall be calibrated to give an accuracy of the cooling water temperature rise (θ_{w2} - θ_{w1}) better than ± 0,02 K. The reference air on coil temperature sensor shall be calibrated together with the water temperature probes to give an accuracy of measurement of the temperature difference between the reference air temperature and the inlet and outlet water temperatures equal to or better than ± 0,02 K. The water flow rate through the test object shall be measured with a flow meter calibrated to an accuracy better than 1 % (= ± 0,5 %), (i.e. by a weighting method).

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

The instrumentation used to measure local air temperature and local mean air velocity in the beam convective air stream shall be in accordance with EN 13182.

4.4 Test procedure

4.4.1 Test set up

The test object shall be installed symmetrically about the centre of the ceiling and with the longest side parallel to the longest room side. The minimum distance between walls and the beam shall be 200 mm. The height from the top of the beam to the ceiling shall be 300 mm.

If more than one test object is needed to comply with 4.4.2, 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 should be insulated with a maximum thermal conductivity of 4 $W/m^2 K$.

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 minute) are within the following limits for at least 60 min:

— Reference temperature (air on coil temperature): 0,05 K

— Interior room surface temperatures: 0,5 K

— Mean water temperature: 0,05 K

— Cooling water flow rate: 1 % of nominal

4.4.3 Measurements

The measurements shall be carried out at steady state conditions with at least 3 different $\Delta\theta$: 6 K ± 1K, 8 K ± 1K and 10 K ± 1K, for each water flow rate.

The reference air on coil temperature (θ_{ac}) 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).

The measurements are carried out with at least 20 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 air on coil temperature of less than 1,0 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 room temperature. The maximum temperature difference between any point of the inner walls and floor, outside the direct convective down flow from the beam, during the test shall be less than 1,0 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 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_{vN}). One other test series should be carried out with half of the nominal water flow rate.

NOTE Heat balance can be used to check reliability of results in the case of internal heat sources similar to procedures as in EN 14240.

At each of the $\Delta\theta$ values used, the maximum local mean air velocity and corresponding local air temperature shall be measured at 0,75 m below the beam discharge plane.

Normally the maximum local air velocity will be found at the centre of the beam discharge length directly beneath the centre of the beam discharge point. The convective stream trajectory can be established by use of smoke.

If due to beam construction the location of the maximum local air velocity is in doubt or may vary with $\Delta\theta$ then an air velocity measurement traverse along the beam length and across the convective air stream should be undertaken to establish the location of the maximum local mean air velocity.

4.4.4 Expression of results

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

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

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

$$P_L = P / L$$

The specific cooling capacity shall be plotted in a diagram as a function of the temperature difference ($\Delta\theta$) between the on coil temperature (reference room temperature) and the mean cooling water temperature. A curve of best fit shall be drawn through the plotted points for each test series. The curves shall be of the form:

$$P_L = k \cdot \Delta\theta^{\,n}$$ (see Figure 1)

k is a characteristic constant

n is the exponent

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 an extra information.

5 Uncertainty

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

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

The maximum uncertainty of the individual measurements shall be as follows:

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 ($\Delta\theta$):	± 0,1 K	$r_3 \approx$ 2,5 % (at $\Delta\theta$ = 8 K)
Test room configuration (internal/external heat sources)		$r_4 \approx$ 3 %[1)]

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 (cooling length, inside pipe diameter etc.);

f) description of the installation of the test object(s) in the test room;

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

h) test results for each measuring point (as described in 4.2, 4.3.2 and 4.4.3);

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

j) sample sheet of measurements and results;

k) date and authorisation;

l) each page of the test report should have a page number and the total number of pages;

m) on each page a footnote that it is not allowed to copy single pages of the report.

1) This value is based on comparative studies taking into account the different test arrangements allowed by the standard.

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

Results of Measurement								
			Measuring point					
Number			1	2	3	4	5	6
Date			15.06	15.06	16.06			
cooling water flow rate		q_m	0,1496	0,1515 kg/s	0,1509 kg/s			
temperatures	water inlet	θ_{W1}	15,39 °C	17,33 °C	19,33 °C			
	water outlet	θ_{W2}	16,90 °C	18,51 °C	20,18 °C			
	globe	θ_g	26,42 °C	26,07 °C	25,73 °C			
	air – 1,7 m	$\theta_a 1.7$	26,8 °C	26,4 °C	26,0 °C			
	air – 1,1 m	$\theta_a 1.1$	26,9 °C	26,4 °C	26,0 °C			
	air – 0,1 m	$\theta_a 0.1$	26,6 °C	26,3 °C	25,9 °C			
	surface wall 1	θ_{W1}	25,8 °C	25,8 °C	25,8 °C			
	surface wall 2	θ_{W2}	26,0 °C	26,0 °C	26,0 °C			
	surface wall 3	θ_{W3}	25,7 °C	25,7 °C	25,7 °C			
	surface wall 4	θ_{W4}	26,0 °C	25,9 °C	25,9 °C			
	surface inside floor	θfloor	25,9 °C	25,9 °C	25,9 °C			
	surface inside ceiling	θceiling	25,9 °C	25,9 °C	25,9 °C			
	air - oncoil	θ_{ac}	19,6 °C	20,6 °C	21,6 °C			
Air temperature 0,75 m below beam		θ_L	18,4 °C	19,1 °C	19,5 °C			
Main air velocity 0,75 m below beam		V_L	0,23 m/s	0,18 m/s	0,15 m/s			
heating capacity - dummies		P_s	927,9 W	717,9 W	518,1 W			

Reference areas		
test room area	$_{At}$	14,44 m²
total length	L_t	3,00 m
active length	L	2,85 m

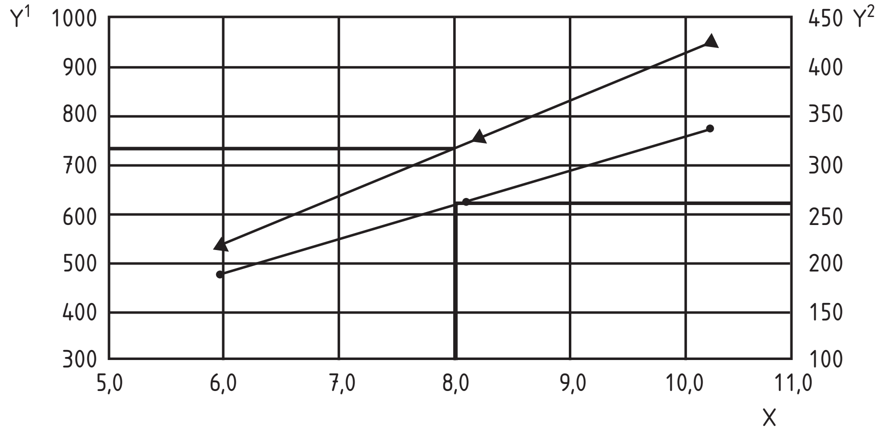
Measures	
Testroom-height	2,80 m
Testroom-length	3,80 m
Testroom-width	3,80 m

Calculations on Measurement								
			Measuring point					
No.			1	2	3	4	5	6
Reference temperature		θ_{ac}	26,42 °C	26,07 °C	25,73 °C			
Δθ	water temperature rise	$\Delta\theta_W$	1,52 K	1,18 K	0,85 K			
	reference- water mean	$\Delta\theta$	10,28 K	8,14 K	5,95 K			
cooling capacity	specific; testroom area	P_{ht}	-65,8 W/m²	-51,9 W/m²	-37,3 W/m²			
	specific; total length	P_{LT}	-317,0 W/m	-249,6 W/m	-179,4 W/m			
	specific; active length	P_L	-333,6 W/m	-262,7 W/m	-188,9 W/m			
	total	P	-950,9 W	-748,8 W	-538,3 W			
Heat transfer test room periphery		P_t	-20,0 W	-11,8 W	-2,2 W			
Heat balance		ΔP	-43,0 W	-42,7 W	-22,4 W			
Heat balance max - value		0.05 P	45,5 W	37,4 W	26,9 W			

Result of measurement		
nominal specific capacity	P_{LN}	257,1 W/r
coefficient	k	28,906
exponent	n	1,051

$$P_{LN} = k\,\Delta\theta^n$$

nominal capacity at Δθ = 8K



Key

X Temperature difference Δθ in K

Y[1] Total cooling capacity P in W

Y[2] Specific cooling capacity P_{LN} in W/m

Figure 1 — Typical example of measurements and results

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