Single burner gas-fired overhead radiant tube heaters for non-domestic use —

Part 2: Rational use of energy

The European Standard EN 416-2:2006 has the status of a British Standard

ICS 97.100.20

National foreword

This British Standard is the official English language version of EN 416-2:2006. Together with BS EN 419-2:2006, it supersedes DD ENV 1259-1:1994, DD ENV 1259-2:1996 and DD ENV 1259-3:1996 which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GSE/20, Non-domestic space heaters (Gas), 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;

— 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.

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English Version

Single burner gas-fired overhead radiant tube heaters for non-domestic use - Part 2: Rational use of energy

Tubes radiants suspendus à monobrûleur à usage non domestique utilisant les combustibles gazeux - Partie 2 : Utilisation rationnelle de l'énergie

Gasgeräte-Heizstrahler - Dunkelstrahler mit einem Brenner mit Gebläse für gewerbliche und industrielle Anwendung - Teil 2: Rationelle Energienutzung

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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.

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Foreword

This European Standard (EN 416-2:2006) has been prepared by Technical Committee CEN/TC 180 “Non-domestic gas-fired overhead radiant heaters”, 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of an identical text or by endorsement, at the latest by December 2006, and conflicting national standards shall be withdrawn at the latest by December 2006.

This European Standard supersedes ENV 1259-1:1994, ENV 1259-2:1996 and ENV 1259-3:1996

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this European Standard.

This part of EN 416 complements EN 416-1: “Single burner gas-fired overhead radiant-tube heaters - Part 1: Safety”.

It is intended that this standard is reviewed 3 years after publication.

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, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies the requirements and test methods for the rational use of energy of non-domestic gas fired overhead radiant tube heaters incorporating a single burner system under the control of an automatic burner control system, referred to in the body of the text as 'appliances'.

This standard is applicable to Type A_2, A_3, B_{12}, B_{13}, B_{22}, B_{23}, B_{42}, B_{43}, B_{52}, B_{53}, C_{12}, C_{13}, C_{32} and C_{33} appliances intended for use in other than domestic dwellings, in which the supply of combustion air and/or the evacuation of the products of combustion is achieved by mechanical means located upstream of the draught diverter, if provided.

This standard is not applicable to:

a) appliances designed for use in a domestic dwelling;

b) outdoor appliances;

c) appliances of heat input in excess of 120 kW (based on the net calorific value of the appropriate reference test gas);

d) appliances having fully pre-mixed gas and air burners in which :

   1) either the gas and all the combustion air are brought together just before the level of the combustion zone; or

   2) pre-mixing of the gas and all combustion air is carried out in a part of the burner upstream of the combustion zone.

This standard is applicable to appliances which are intended to be type tested. Requirements for appliances which are not intended to be type tested need to be subject to further consideration.

2 Normative references

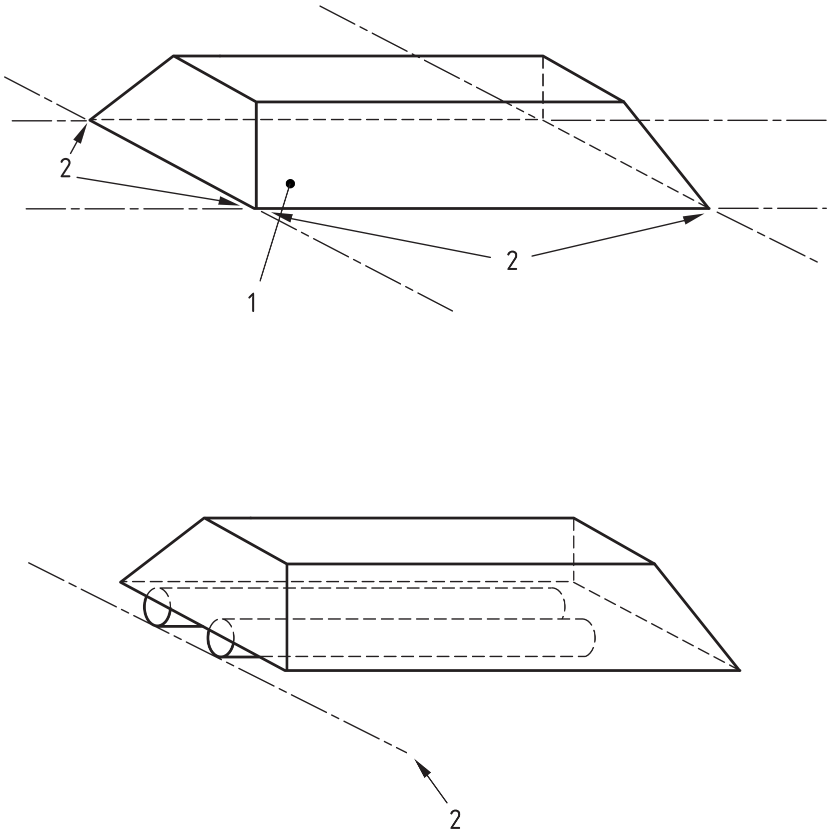
The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 416-1: 1999, *Single burner gas-fired overhead radiant tube heaters — Part 1: Safety*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in Clause 3 of EN 416-1: 1999 apply together with the following.

3.1
radiation reference plane
flat horizontal surface bounded by the lower edge of the reflector or, in the case where radiant parts project below this lower edge of the reflector, the flat horizontal surface touching the lowest radiant part (see Figure 1)



Key
1 Reflector
2 Reference plane

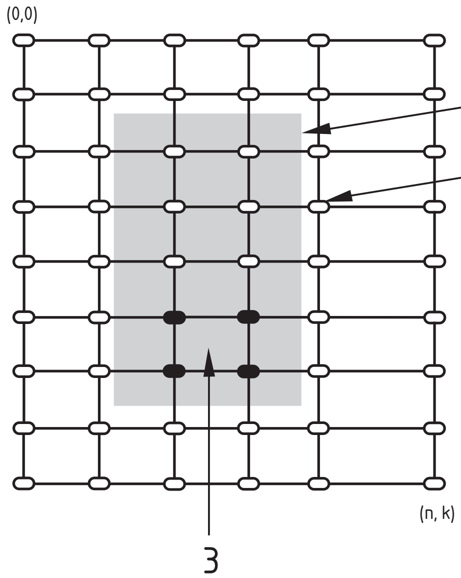
Figure 1 — Radiation reference plane

3.2
irradiance (*E*)
radiant power per unit area (W/m^2) incident upon a surface

3.3
radiant factor (R_f)
heat emitted by the appliance through the radiation reference plane divided by the net heat input of the test gas

3.4
measuring plane (Test method B only)
plane parallel to the radiation reference plane and 100 mm ± 3 mm below it

3.5
measuring grid (Test method B only)
regular arrangement in the measuring plane of straight lines running parallel and perpendicular to the longitudinal axis of the appliance with sufficient precision (± 1 mm). The nodal points of the measuring grid are located at the points of intersection of these lines (see Figure 2) such that the distance between all adjacent nodes points on these lines is 100 mm ± 2 mm



Key
1 Heater
2 Nodal point
3 Measuring cell F_{ij}

Figure 2 — Measuring grid (Test method B)

4 Classification of appliances

4.1 Classification according to the nature of the gases used

The requirements of 4.1 of EN 416-1:1999 apply.

4.2 Classification according to the gases capable of being used

The requirements of 4.2 of EN 416-1:1999 apply.

4.3 Classification according to the mode of evacuation of the combustion products

The requirements of 4.3 of EN 416-1:1999 apply.

5 Symbols

The symbols shown in Table 1 are used in this standard.

Table 1 — Symbols

Symbol	Title	Unit
α_{CO_2}	Coefficient in equation for k_{co2}	$kPa^{-1}\ m^{-1}$
α_{H_2O}	Coefficient in equation for k_{mo}	$kPa^{-1}\ m^{-1}$
A_{CO_2}	Absorption factor of carbon dioxide	—
A_{H_2O}	Absorption factor of water vapour	—
a	Reflector length	mm
A_{TOT}	Radiant correction factor for water vapour and CO_2 in air (see Annex E)	—
b	Reflector width	mm
c	Distance between two nodal points parallel with the longitudinal axis	mm

Symbol	Title	Unit
$C\alpha\beta$	Surface area correction factor	—
D	Average thickness of radiating gas layer (i.e. from measurement point to radiation reference plane)	m
ε_{CO_2}	Emission factor of carbon dioxide	—
ε_{H_2O}	Emission factor of water vapour	—
E	Actual irradiance from overhead radiant heater	W/m^2
E_a	Actual irradiance output by appliance in air	W/m^2
E_{ij}	Irradiance of the appliance measured at the nodal points of the measurement	W/m^2
$\overline{E_{if}}$	Average irradiance over the measurement grid F_{ij}	W/m^2
F_w	Window correction factor	—
H_i	Net calorific value of the test gas (at 15 °C, 1013,25 mbar, dry gas)	W h/m^3
k_{CO_2}	Coefficient in equation for emission factor of carbon dioxide	kPa^{-1} m^{-1}
k_{H_2O}	Coefficient in equation for emission factor of water vapour	kPa^{-1} m^{-1}
L	Length of reference surface cylinder	m
N	Number of arc positions along the half cylinder (see Figure 2)	—
n	Coefficient in equations for k_{CO_2} and k_{H_2O}	—
P_{CO_2}	Partial pressure of carbon dioxide in ambient air	kPa
P_{H_2O}	Partial pressure of water vapour in ambient air	kPa
$p_{max,H20}$	Saturated vapour pressure	mbar
p	Gas supply pressure	mbar
p_a	Atmospheric pressure	mbar
p_W	Saturation vapour pressure of fuel gas at temperature t_g	mbar
Q_m	Measured heat input based on the net calorific value of the test gas	W
$Q_{(R)C}$	Radiant output after correction for absorption of radiation in air	W
$Q_{(R)M}$	Measured radiant output	W
R	Radius to radiometer from centre of reference plane	m
R_f	— Radiant factor	—
S	Radiometer sensitivity	µV/(W/m^2)
t_A	Ambient air temperature	°C
t_g	Gas temperature at measuring point	°C
t_s	Sensor temperature	°C
U	Sensor voltage	v
V	Gas volume input at test conditions	m^3/h
V_b	Sensor voltage recorded with radiation shield in place	µV
V_t	Sensor voltage recorded without radiation shield in place	µV
V_o	Gas volume rate under reference conditions (at 15 °C, 1013,25 mbar, dry gas)	m^3/h
ε_{H_2O}	Emissivity of water	—

6 Requirements for the rational use of energy

When mounted horizontally in accordance with the manufacturer's instructions and measured by one of the methods given in 7.2 the radiant factor of the appliance, adjusted to the nominal heat input, shall be in accordance with the values given in Table 2.

Table 2 — Radiant factor for appliances mounted horizontally

Class	Radiant Factor
1	$> 0,4$ to $\leq 0,5$
2	$> 0, 5$

7 Test methods

7.1 General

The test shall be carried out with the appliance mounted horizontally in accordance with the manufacturer's instructions.

The requirements of 7.1 of EN 416-1: 1999 apply unless otherwise specified.

7.2 Radiant factor

7.2.1 General

7.2.1.1 Working area (requirements applicable to all methods of test)

The working area shall be of a size to allow installation of the appliance and shall:

a) provide sufficient ventilation to remove the combustion products and heat generated by the appliance;

b) have an ambient air temperature of 20 °C ± 5 °C;

c) allow the sensors to be positioned free from draughts;

The sensor temperature shall be checked before and after measurements are taken and:

d) for air cooled sensors shall be 20 °C ± 5 °C; and

e) for water cooled sensors, the temperature of the cooling water shall not change by more than ± 5 °C during the test.

7.2.1.2 Choice of test method

The radiant factor of the appliance may be determined either by the method described in 7.2.2 or by the method described in 7.2.3.

7.2.2 Method A

7.2.2.1 Installation and adjustment of the appliance

The appliance shall be installed at a height of between 2 m and 2,5 m and initially adjusted in accordance with the requirements of 7.1.

The test shall be carried out with the appliance adjusted to its nominal heat input or, in the case of a range-rated appliance, to its minimum and maximum nominal heat inputs [1](see 7.1.3.2.3 of EN 416-1: 1999) and supplied with one of the reference gases for the category to which the appliance belongs (see 7.1.1 of EN 416-1: 1999).

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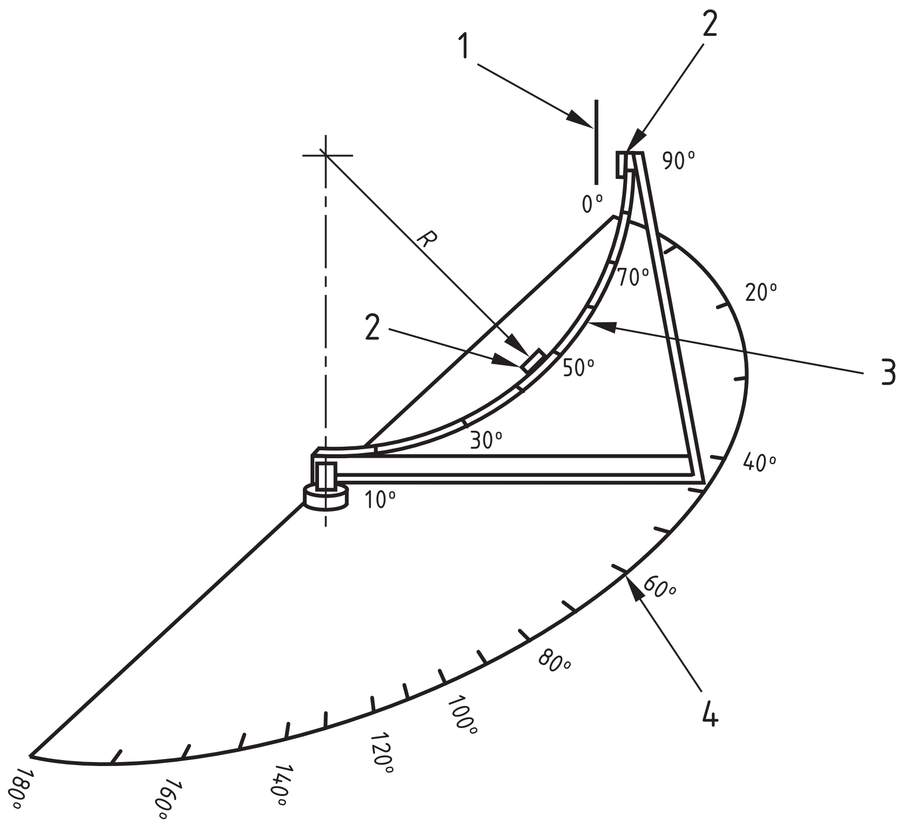
[1] A test at the maximum nominal heat input need not be applied if it is known that the lowest radiant output is achieved at the minimum nominal heat input.

7.2.2.2 Apparatus

7.2.2.2.1 Mechanical apparatus

In order to move the sensor positions, in an imaginary envelope around the appliance, a mobile, rigid test rig having a graduated, circular metal arc, with sensors attached, pivoted on its vertical axis is required. The radius of the metal arc shall be within the range given in Figure 3.

NOTE It is important to check that the maximum irradiance does not exceed the maximum value allowed for the instrument.



Key

1 Removable radiation shield

2 Radiometer

3 Parallel

4 Meridian

R Radius measured from the arc centre to the surface of the radiometer. The radius shall be in the range 1,54 m to 1,88 m. For any one measurement, the radius shall not vary by more than ± 20 mm

Figure 3 — Test rig (Test method A)

Test equipment shall:

a) for an appliance with a length of more than 1,3 m, provide adjustment to allow the arc centre to coincide with either end of the reference plane;

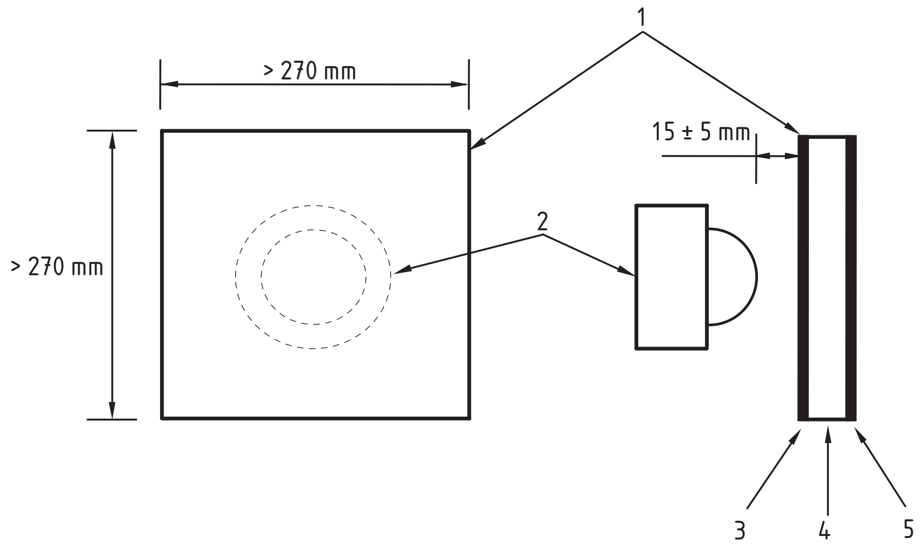
b) for an appliance with a length of 1,3 m or less, make the arc centre coincident with the centre of the reference plane (see Figure 1);

c) be installed in a test area with sufficient floor area to allow marking on the floor of the measurement positions;

d) have a detachable or retractable radiation shield in front of each sensor to mask it from the appliance. The radiation shield shall be designed and arranged so that the surface of the shield facing the sensor is at thermal equilibrium under the ambient conditions of the working area (see 7.2.1.1). The general arrangement and construction of the radiation shields is given in Figure 4;

e) provide an individual radiation shield for each sensor which does not reflect radiation towards any other sensor(s);

f) if appropriate, provide a guide rail to position the arc along the length of the appliance.



Key
1 Radiation shield
2 Sensor
3 Reflective aluminium sheet
4 15 mm insulation (e.g. Rockwool or Polystyrene)
5 Matt black non-reflective surface

Figure 4 — Radiation shield (Test method A)

7.2.2.2.2 Measurement apparatus

7.2.2.2.2.1 Sensor characteristics

Sensors used shall :

a) have a sensitivity factor that does not change by more than ± 3 % in an ambient temperature range of 15 °C to 30 °C;

b) have a sensitivity that is constant either in the wavelength range 0,8 µm to 40 µm, or in another wavelength range which shall be stated in the test report (see 7.2.2.5)[2];

c) have a span angle ≥ 170 °C. There shall not be a large variation in sensitivity with a change in the radiation angle of incidence;

2) This may be necessary for the purposes of calibration.

d) have a sensitivity which is constant within an irradiance range of 10 W/m^2 to 1 100 W/m^2;

e) in order to eliminate the influence of draughts on the radiometer, a suitable window shall be installed and :

1) have a viewing angle ≥ 170°;

2) maximise radiation transmission in the range 2 µm to 9 µm.

f) window correction factor (F_w) shall be calculated for each window (see Annex D).

7.2.2.2.2.2 Sensor positions

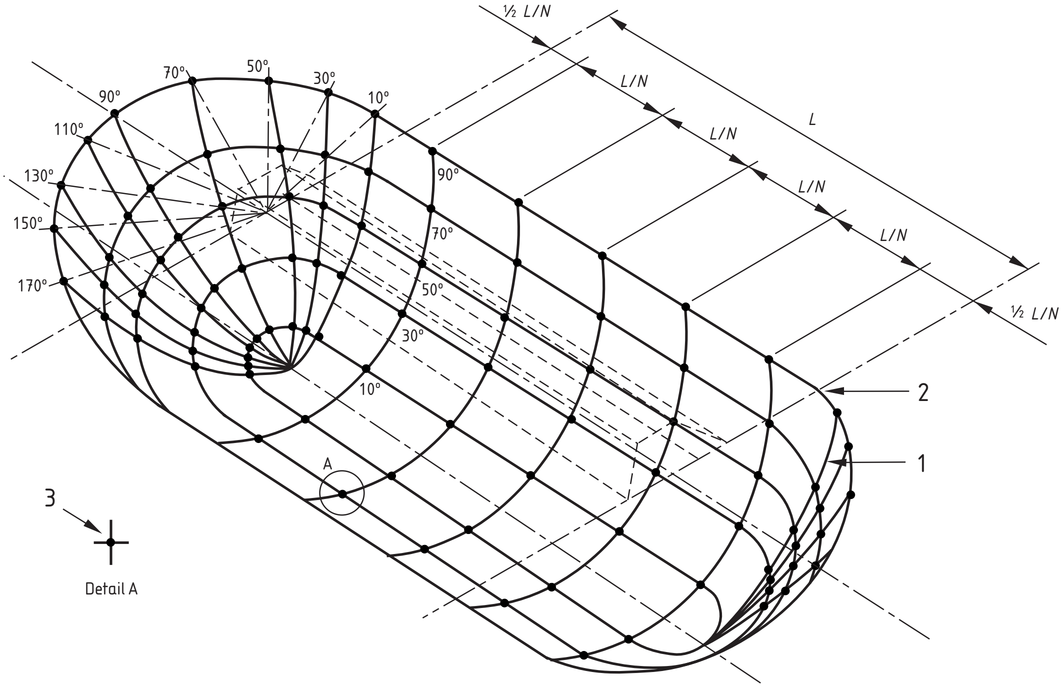
The sensors shall be positioned (see Figures 3, 5a) and 5b)) such that:

a) where a single sensor is used, it shall be capable of being moved along the length of the metal arc and of being positioned every 20° ± 1° (between 10° and 90°);

b) where multiple sensors are used, they shall be positioned along the length of the arc every 20°± 1° (between 10° and 90°);

c) measuring surface shall be tangential to the surface generated by movement of the metal arc.

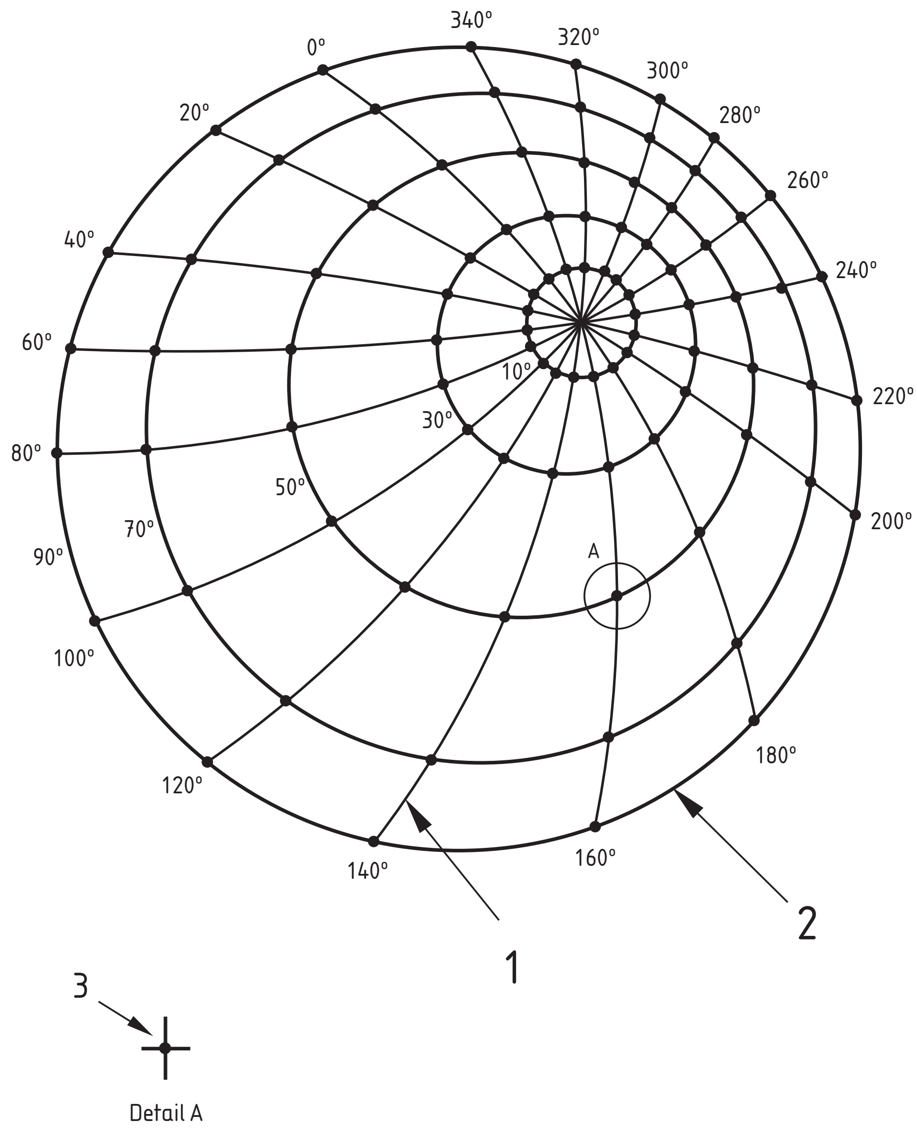
NOTE It is recommended that the face in front of the sensor thermopiles should be protected from irradiance and dust when not being used for taking measurements. Care should be taken to prevent accidental re-radiation from reflecting surfaces (e.g. white clothes and equipment not necessary for the test) within the 180° view of the radiometer.



Key

1	Meridian
2	Parallel
3	Identification of sensor positions
A	Sensor position
L	Reference surface cylinder length
N	Number of arc positions along the cylinder length

a) Integrating surface (Test method A) – Appliance greater than 1,3 m in length



Key

1	Meridian
2	Parallel
3	Sensor position notation
A	Sensor position

b) Integrating surface (Test method A) – Appliance less than 1,3 m in length

Figure 5 — Appliance integrating surface (Test method A)

7.2.2.3 Working area

Working areas shall:

a) have walls and ceilings that are isolated from exterior influences (e.g. sunlight through windows and other heating equipment);

b) have interior surfaces treated so as to reduce spurious radiation reflection (e.g. matt non-reflective surfaces);

c) be arranged such that the wall and ceiling temperatures do not change by more than ± 5 °C during the measurement phase of testing.

7.2.2.4 Procedure

7.2.2.4.1 Integration surface

The integration surface (see Figures 5a) and 5b)) shall be the envelope generated by moving the arc such that:

a) for an appliance less than or equal to 1,3 m long, the centre of the hemisphere shall be on the centre of the radiating reference surface;

b) for an appliance of length greater than 1,3,m, it describes a half cylinder of length equal to the effective length of the emitter of which the axis coincides with the reference surface. This surface shall be terminated at its extremities by two half hemispheres;

c) where the emitter is symmetrical (e.g. a linear tube) examination of the radiation shall be limited to :

1) in the case of an appliance of less than or equal to 1,3 m long, a quarter hemisphere (the result shall be multiplied by two); or

2) in the case of an appliance of length greater than 1,3 m to a quarter cylinder plus two quarter hemispheres (the result shall be multiplied by two).

7.2.2.4.2 Measurement

Connect each sensor to a millivoltmeter of the potentiometric type, electronic type or electronic device with an input impedance of at least 1 MΩ and a sensitivity of 1 μV.

Make the measurements in a still atmosphere with the appliance in thermal equilibrium when operating under the adjustment conditions described in 7.2.2.1.

NOTE It is important to measure the outside temperature of the instrument to ensure it is not being overheated.

The measurement points shall be situated at the intersection of the parallels and the meridians (see Figures 5a) and 5b)) such that:

a) for an appliance less than or equal to 1,3 m long, the measurement point shall be on the hemisphere and the intersections shall be at meridians 0°, 20°, 40° etc, up to 180°, with parallels 10°, 30°, 50° etc. up to 90° (See Figure 5b));

b) for an appliance of length greater than 1,3 m, the measurement point shall be on the half hemisphere (see Figure 5a)), the intersections at the extremities shall be at meridians 10°, 30°, 50° etc. up to 170°, with parallels 10°, 30°, 50° etc. up to 90°.

On the half cylinder required for a reference surface of length *L* for a number of measurements *N*, the intersections shall be at the points given by Expression (1).

$$\frac{L}{2N'}\frac{3L}{2N'}\frac{5L}{2N'}.........\frac{(2N-1)L}{2N} \qquad (1)$$

where :

L is the reference surface length;

N is the number of measurements taken.

with parallels 10°, 30°, 50° etc up to 90°.

L/*N* shall have a maximum value of 0,8 m.

7.2.2.4.3 Determination of radiant factor

The test shall be performed in stages by:

a) measuring the voltage at all points shown in the imaginary envelope. These measurements shall be made with and without the radiation shield in place (see Figure 4).

The actual irradiance *E* can then be calculated using Equation (2).

$$E = \frac{(V_t - V_b)}{F_W S} \qquad (2)$$

where :

V_t is the sensor voltage recorded without the radiation shield in place in µV;

V_b is the sensor voltage recorded with the radiation shield in place in µV;

F_w is the window correction factor;

S is the radiometer sensitivity in µV/(W/m^2).

b) integrating over the envelope of each quarter sphere and quarter cylinder to obtain the energy received from the appliance and its contribution to the radiant output (see Annexes A and B).

c) determining the measured radiant output ($Q_{(R)M}$), using Equation 3 or 4 as appropriate :

1) for an appliance less than or equal to 1,3 m long :

$$Q_{(R)M} = Q_{(R)5} \qquad (3)$$

where :

$Q_{(R)5}$ is the radiant output of the hemisphere in W.

2) for an appliance of length greater than 1,3 m :

$$Q_{(R)M} = Q_{(R)1} + Q_{(R)2} + Q_{(R)3} + Q_{(R)4} \qquad (4)$$

where :

$Q_{(R)1}$ is the radiant output of the quarter sphere (burner end) in W;

$Q_{(R)2}$ is the radiant output of the quarter sphere (opposite end) in W;

$Q_{(R)3}$ is the radiant output of the quarter cylinder (burner side) in W;

$Q_{(R)4}$ is the radiant output of the quarter cylinder (opposite side) in W.

d) measure the heat input to the appliance (Q_m) using Equation (5) :

$$Q_m = V_o(H_i) \qquad (5)$$

where :

V_o is the gas volume rate under reference conditions in m^3/h;

H_i is the net calorific value of the test gas in Wh/m^3; and

$$Vo = V \left(\frac{(288{,}15)}{273{,}15 + t_g} \times \frac{(p_a + p - p_w)}{1013{,}25} \right)$$

where :

V is the gas volume input at the test conditions in m^3/h ;

p is the gas supply pressure mbar;

p_a is the atmospheric pressure in mbar;

p_w is the saturation vapour pressure of the fuel gas at temperature t_g in °C;

t_g is the gas temperature at the measuring point in °C

NOTE 1 Q_m is derived from the gas volume flow rate under reference conditions and the net calorific value of the gas used for testing, utilising the units specified in Clause 5. Equation (6) is not the same as that given in EN 416-1 for the calculation of the nominal heat input, which is not appropriate in this instance.

e) calculate the radiant factor (R_f) using Equation (6) (see Annex A).

$$R_f = \frac{Q_{(R)_C}}{Q_m} \qquad (6)$$

where :

$Q_{(R)c}$ is the radiant output after correction for the absorption of radiation in air in W;

Q_m is the measured heat input based on the net calorific value of the test gas in W; and

$$Q_{(R)c} = \frac{Q_{(R)M}}{1 - A_{TOT}}$$

where :

A_{TOT} is the radiant correction factor for water vapour and CO_2 in air

NOTE 2 For the calculation of A_{TOT} see Annex E.

The requirements given in Clause 6 shall be satisfied.

7.2.2.5 Test report

In view of the complexity of the test, it is recommended that test results are recorded in a test report (see Annexes A, B and C for examples).

7.2.3 Method B

7.2.3.1 General

The appliance shall be installed in accordance with the requirements of 7.1 and suspended at least 1,2 m above the floor.

7.2.3.2 Test equipment

7.2.3.2.1 General radiometer requirements

For the measurements, one or more radiometers can be used at the same time, each having a sensitivity to irradiance in a minimum wavelength range of 0,8 µm to 40 µm.

Each radiometer shall be calibrated in accordance with the requirements of Annex I.

Only radiometers that have thermostatically controlled water-cooling and nitrogen purge for the integrating sphere shall be used.

NOTE An example of a proved and tested radiometer design is given in Annex H.

7.2.3.2.2 Mechanical test equipment

Test equipment shall:

a) if it is mechanical equipment, enable the appliance to be suspended horizontally in accordance with the requirements of 7.1; and

b) provide a stable mobile test arrangement enabling the radiometer to be adjusted accurately in the measuring plane.

NOTE Adjustment may be achieved by hand or automatically.

7.2.3.2.3 Radiometer measurement positions

Before commencing the test, the first and last node points (measurement points) shall be established where the parallel and perpendicular lines intersect. This is achieved by measuring the irradiance at the edge of the reflector and the crossover points or nodes are where irradiation is smaller than 1 % of the maximum measured value under the appliance.

The radiometer shall be positioned at the nodal points of the measurement grid (see Figure 2).

7.2.3.3 Working area

The test shall be carried out in a working area having a floor with a non-reflecting surface.

7.2.3.4 Test procedure

7.2.3.4.1 Measuring principle

Radiant output is determined by means of a radiometric method in which the irradiance in the measuring plane is measured and the measured values are integrated over the area of the measuring grid.

7.2.3.4.2 Measuring method

The radiometer is placed at each of the nodal points specified in 3.5 with a maximum deviation (for each of the three axes) of 3 mm and a measurement of the irradiance is taken as soon as the reading is stable.

The radiometer axis shall not incline by more than 2° from the perpendicular.

NOTE It is recommended that the measuring sequence is recorded using an automatic system.

7.2.3.5 Calculation of radiant output

The radiant output ($Q_{(R)M}$) corresponds to the sum of all the products between the individual node surface and the arithmetic mean of the measured values of the irradiance of the four nodes forming each node surface (Figure 2).

The appliance irradiance (E_{ij}) measured at the nodes is given by Equation (7).

$$E_{ij} = U/S \quad \text{W/m}^2 \qquad (7)$$

where :

U is the sensor voltage in µV;

S is the radiometer sensitivity in µV/W/m²

and the average appliance irradiance ($\overline{E_{ij}}$) measured at the nodes is given by Equation (8).

$$\overline{E_{ij}} = \frac{E_{i-1,j-1} + E_{i-1,j} + E_{i,j-1} + E_{i,j}}{4} \quad \text{W/m}^2 \qquad (8)$$

where :

$i \in (1,2.......,n)$ and

$j \in (1,2.......,k)$

The radiant output ($Q_{(R)M}$) is then given by Equation (9).

$$Q_{(R)M} = \sum_{\substack{(i=1)\\(j=1)}}^{\substack{(i=n)\\(j=k)}} F_{ij} \times \overline{E}_{ij} \qquad (9)$$

where :

F_{ij} is the area of the measurement cell in m² (see Figure 2);

$\overline{E}_{ij}$ is the average irradiance of the measurement cell F_{ij} in W/m²

7.2.3.6 Calculation of heat input

The heat input to the appliance is given by Equation (5).

$$Q_M = V_o(H_i)$$

and

$$V_o = V \left(\frac{(288,15)}{273,15 + t_g} \times \frac{(p_a + p - p_w)}{1013,25} \right)$$

NOTE This heat input is derived from the gas volume flow rate under reference conditions and the net calorific value of the gas used for testing, utilising the units specified in Clause 5. The equation is not the same as that given in EN 416-1 for the calculation of the nominal heat input, which is not appropriate in this instance.

7.2.3.7 Calculation of radiant factor

The radiant factor (R_f) of the appliance is given by Equation (6).

$$R_f = \frac{Q_{(R)c}}{Q_M}$$

and :

$$Q_{(R)c} = \frac{Q_{(R)M}}{1\text{-}A_{TOT}}$$

The requirements of Clause 6 shall be satisfied.

7.2.3.8 Test report

In view of the complexity of the test, it is recommended that test results are recorded in a test report (see Annex F for examples).

Annex A
(informative)

Recording test data (Test method A)

A.1 General information to be recorded

Equipment type : ______________________

Model : ______________________________

Supplier : ____________________________

Manufacturer : ________________________

Appliance category : ___________________

Reference gas : ________________________

Technician : ___________________________

Test date :____________________________

Nominal heat input : _________________ kW

Measured heat input (Q_M) : ____________ W

Ambient air relative humidity : ____________

Air temperature (before) : _____________ °C

Flue gas temperature (before) : ________ °C

Air temperature (after) : ________________ °C

Flue gas temperature (after) : __________ °C

Flue gas (O_2 or CO_2) (before) : ___________

Flue gas (O_2 or CO_2) (after) : _____________

Quarter sphere/cylinder radius : ________ m

Radiometer sensitivity : __________ μV/W/m^2

Tube length (L) : ____________________ m

Number of cylinder arc positions (N) : ______

L/N : _________________________________ m

A_{TOT} : _________________________________

A.2 Measurement results

Measurement position		Test measurement (W)
Quarter sphere (burner end)	$Q_{(R)1}$	
Quarter sphere (opposite end)	$Q_{(R)2}$	
Quarter cylinder (burner side)	$Q_{(R)3}$	
Quarter Cylinder (opposite side)	$Q_{(R)4}$	
Total $Q_{(R)M}$ (= $Q_{(R)1}$+ $Q_{(R)2}$+ $Q_{(R)3}$+ $Q_{(R)4}$)		

Measured radiant output ($Q_{(R)M}$) for an appliance less than or equal to 1,3 m long = $Q_{(R5)}$ ______W

Radiant output ($Q_{(R)c}$) after correction for absorption of radiation in air :

$$Q_{(R)c} = Q_{(R)M} /(1 - A_{TOT}) = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \text{ W}$$

Radiant factor (R_f) :

$$R_f = Q_{(R)c} / Q_M = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}$$

Annex B
(informative)

Blank forms (Test method A)

B.1 Model test result form - Quarter sphere burner end and opposite end

Quarter sphere (burner end) ($Q_{(R)1}$)														
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV								ΣI µV	Cαβ	Δcosα	$1/SF_w$ W/(m²/µV)	E=Σi.Cαβ. Δcosα1/SF_w W/m²
	10°	30°	50°	70°	90°	110°	130°	150°	170°					
90°											0,5	0,347		
70°											1	0,327		
50°											1	0,266		
30°											1	0,174		
10°											1	0,060		
													Total ΣE	

Name :	
Date :	

The radiant output ($Q_{(R)1}$) over the surface of the quarter sphere is given by :

$$Q_{(R)1} = \frac{\sum E}{9} \times \pi R^2 \text{\_\_\_\_\_\_\_\_\_ W}$$

Quarter sphere (Opposite end) ($Q_{(R)2}$)														
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV								ΣI µV	Cαβ	Δcosα	$1/SF_w$ W/(m²/µV)	E=Σi.Cαβ. Δcosα1/SF_w W/m²
	10°	30°	50°	70°	90°	110°	130°	150°	170°					
90°											0,5	0,347		
70°											1	0,327		
50°											1	0,266		
30°											1	0,174		
10°											1	0,060		
													Total ΣE	

Name :	
Date :	

The radiant output ($Q_{(R)2}$) over the surface of the quarter sphere is given by :

$$Q_{(R)2} = \frac{\sum E}{9} \times \pi R^2 \text{\_\_\_\_\_\_\_\_\_ W}$$

B.2 Model test result form - Quarter cylinder (Burner side and opposite side)

Quarter cylinder (Burner side) ($Q_{(R)3}$)													
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV									ΣI µV	Cαβ	1/SF$_w$ W/(m^2/µV)	E=Σi.Cαβ. 1/SF$_w$ W/m^2
	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7	Pos 8	Pos N				
90°											0,5		
70°											1		
50°											1		
30°											1		
10°											1		
												Total ΣE	

Name :	
Date :	

The radiant output ($Q_{(R)3}$) over the surface of the quarter cylinder is given by :

$$Q_{(R)3} = \frac{\sum E}{4{,}5N} \times \frac{\pi RL}{2} = \_\_\_\_\_\_\_\_\_\_ \text{ W}$$

Quarter cylinder (Opposite side) ($Q_{(R)4}$)													
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV									ΣI µV	Cαβ	1/SF$_w$ W/(m^2/µV)	E=Σi.Cαβ. 1/SF$_w$ W/m^2
	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7	Pos 8	Pos N				
90°											0,5		
70°											1		
50°											1		
30°											1		
10°											1		
												Total ΣE	

Name :	
Date :	

The radiant output ($Q_{(R)4}$) over the surface of the quarter cylinder is given by :

$$Q_{(R)4} = \frac{\sum E}{4{,}5N} \times \frac{\pi RL}{2} = \_\_\_\_\_\_\_\_\_\_ \text{ W}$$

B.3 Model test result form – Half sphere for appliances less than or equal to 1,3 m long

Half sphere ($Q_{(R)5}$)																							
Radiometer position on radius arc (α parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc, α and β meridians µV																	Σi µV	Cαβ	Δcosα	1/SF$_w$ W/(m^2/ µV)	E=Σi.Cαβ.1/ SF$_w$ W/m^2
	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°	200°	220°	240°	260°	280°	300°	320°	340°					
90°																				0,5	0,347		
70°																				1	0,327		
50°																				1	0,266		
30°																				1	0,174		
10°																				1	0,06		
																						Total ΣE	

Name :
Date :

The radiant output ($Q_{(R)5}$) over the surface of the hemisphere is given by :

$$Q_{(R)5} = \frac{\sum E}{18} \times 2\pi R_2 = \_\_\_\_\_\_\_\_\_\_ \text{ W}$$

Annex C
(informative)

Worked example (Test method A)

C.1 Radiant factor - Recorded data and calculation

Equipment type : Radiant tube

Model : 000

Supplier : ABC

Manufacturer : XYZ

Appliance category : I_{2H}

Reference gas : G 20

Technician : WG

Test date : 05-04-94

Nominal heat input : 19,50 kW

Measured heat input (Q_M) : 19 156 W

Ambient air relative humidity : ____________

Air temperature (before) : 23,2 °C

Flue gas temperature (before) : 221 °C

Air temperature (after) : 23,5 °C

Flue gas temperature (after) : 223 °C

Flue gas (O_2 or CO_2) (before) : 5,6

Flue gas (O_2 or CO_2) (after) : 5,7

Quarter sphere/cylinder radius : 1,65 m

Radiometer sensitivity : 8.2 μV/(W/m^2)

Tube length (L) : 4,8 m

Number of cylinder arc positions (N) : 6

L/N : 0,8 m

A_{TOT} : 0,048

Measurement position		Test measurement (W)
Quarter sphere (burner end)	$Q_{(R)1}$	1 537,27
Quarter sphere (opposite end)	$Q_{(R)2}$	641,64
Quarter cylinder (burner side)	$Q_{(R)3}$	3 524,52
Quarter Cylinder (opposite side)	$Q_{(R)4}$	4316,41
Total $Q_{(R)M}$ (= $Q_{(R)1}$+ $Q_{(R)2}$+ $Q_{(R)3}$+ $Q_{(R)4}$)		10 019,84

Radiant output ($Q_{(R)C}$) after correction for absorption of radiation in air :

$$Q_{(R)C} = Q_{(R)M} /(1 - A_{TOT}) = 10\ 019,84/(1-0,048) = 10\ 525,24 \text{ W}$$

Radiant factor (R_f) :

$$R_f = Q_{(R)C} / Q_M = 10\ 525,24/19\ 156 = 0,5494$$

C.2 Radiant output - Recorded data and calculation

C.2.1 Quarter spheres (Burner end and opposite end)

Quarter sphere (burner end) ($Q_{(R)1}$)														
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV									ΣI µV	Cαβ	Δcosα	1/SF$_w$ W/(m^2/µV)	E=Σi.Cαβ. Δcosα1/SF$_w$ W/m^2
	10°	30°	50°	70°	90°	110°	130°	150°	170°					
90°	129	140	167	161	151	153	155	167	161	1324	0.5	0,347	0,122	28,03
70°	1271	1084	924	513	497	636	938	1131	1371	8365	1	0,327	0,122	333,71
50°	1485	1437	1226	1283	1069	1690	1693	1426	1605	12914	1	0,266	0,122	419,09
30°	2620	2234	2071	1947	1935	2524	2999	3654	4201	24205	1	0,174	0,122	513,82
10°	3071	2902	2895	2841	2758	3042	3462	3907	3947	28825	1	0,06	0,122	211,00
													Total ΣE	1 505,65

Name :	WG
Date :	05-04-94

The radiant output ($Q_{(R)1}$) over the surface of the quarter sphere is given by :

$$Q_{(R)1} = \frac{\sum E}{9} \times \pi R^2 = 1537{,}27 \text{ W}$$

Quarter sphere (Opposite end) ($Q_{(R)2}$)														
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV									ΣI µV	Cαβ	Δcosα	1/SF$_w$ W/(m^2/µV)	E=Σi.Cαβ. Δcosα1/SF$_w$ W/m^2
	10°	30°	50°	70°	90°	110°	130°	150°	170°					
90°	89	100	114	114	110	97	91	80	59	854	0,5	0,347	0,122	18,08
70°	562	538	457	449	335	277	387	450	438	3893	1	0,327	0,122	155,31
50°	628	643	762	773	549	513	483	507	591	5449	1	0,266	0,122	176,83
30°	1396	1173	1018	1037	853	823	836	1026	1053	9215	1	0,174	0,122	195,62
10°	1156	1244	1331	1330	1210	1093	1140	1165	1315	11284	1	0,06	0,122	211,00
													Total ΣE	628,44

Name :	WG
Date :	05-04-94

The radiant output ($Q_{(R)2}$) over the surface of the quarter sphere is given by :

$$Q_{(R)2} = \frac{\sum E}{9} \times \pi R^2 \;\; 641{,}64 \text{ W}$$

C.2.2 Quarter cylinders (Burner side and opposite side)

Quarter cylinder (Burner side) ($Q_{(R)3}$)													
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV									ΣI µV	Cαβ	1/SF	E=Σi.Cαβ. 1/SF$_w$ W/m^2
	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7	Pos 8	Pos N			W/(m^2/µV)	
90°	144	144	149	137	1008	660				2242	0,5	0,122	136,76
70°	1842	2164	1991	1606	1126	715				9444	1	0,122	1152,17
50°	2538	2830	2521	1976	1396	939				12200	1	0,122	1488,40
30°	3294	3984	3656	3015	2243	1542				17734	1	0,122	2163,55
10°	3684	4560	4148	3446	2491	1723				19992	1	0,122	2439,02
												Total ΣE	7379,90

Name :	WG
Date :	05-04-94

The radiant output ($Q_{(R)3}$) over the surface of the quarter cylinder is given by :

$$Q_{(R)3} = \frac{\sum E}{4,5N} \times \frac{\pi RL}{2} \quad = 3542,52 \text{ W}$$

Quarter cylinder (Opposite side) ($Q_{(R)4}$)													
Radiometer position on radius α (arc parallel)	Radiometer reading i (having subtracted the voltage from spurious irradiance) at position of radius arc , β meridian µV									ΣI µV	Cαβ	1/SF$_w$	E=Σi.Cαβ. 1/SF$_w$ W/m^2
	Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7	Pos 8	Pos N			W/(m^2/µV)	
90°	98	133	167	178	1832	192				2600	0.5	0,122	158,60
70°	810	1267	1661	1983	2133	1834				9688	1	0,122	1181,94
50°	1019	1534	1984	2269	2442	2032				11280	1	0,122	1376,16
30°	2045	3187	4305	5709	6120	5192				26558	1	0,122	3240,08
10°	2069	3104	4227	5306	5604	4946				25256	1	0,122	3081,23
												Total ΣE	9038,01

Name :	WG
Date :	05-04-94

The radiant output ($Q_{(R)4}$) over the surface of the quarter cylinder is given by :

$$Q_{(R)4} = \frac{\sum E}{4,5N} \times \frac{\pi RL}{2} \quad = 4316,41 \text{ W}$$

Annex D
(normative)

Procedure for measuring the window correction factor (F_w) (Test method A)

The window correction factor (F_w) shall be calculated for each window by:

a) positioning the radiometer under the appliance and at an appropriate distance from it. The window shall then be removed and the sensor moved to give the maximum voltage (V_1);

NOTE It may be necessary to shield the sensor from draughts to minimise the fluctuations in the reading.

b) re-install the window without moving the sensor and note the reduced voltage (V_2);

c) window correction factor (F_W) shall be calculated for each window using Equation D.1.

$$F_w = \frac{V_2}{V_1} \qquad \text{(D.1)}$$

where :

V_1 is the maximum recorded voltage in V;

V_2 is the reduced voltage after moving the sensor in V.

d) procedure described in D.1 a), b) and c) shall be repeated for each type of appliance.

Annex E
(normative)

Correction of measured radiant output for absorption by air (Test methods A and B)

E.1 General

Only the absorption of:

a) water vapour (H_2O); and

b) carbon dioxide (CO_2)

in air are considered.

The requirements of Annex E can be applied to radiant efficiency determined in accordance with the method given in 7.2.2 and/or radiant efficiency determined in accordance with the method given in 7.2.3.

E.2 Mean beam length (*D*)

The mean beam length (*D*) is given by Equation (E.1).

$$D = 1{,}57R - \frac{0{,}57R}{1 + 0{,}183\left(\frac{L}{R}\right)} \qquad \text{(E.1)}$$

where :

L is the length of the radiating surface of the heater in m;

R is the radius to radiometer from centre of the radiation reference plane in m (for method A);or the minimum distance between the radiometer and the radiation reference plane in m (for method B)

E.3 Absorption of radiation by water vapour

The emission factor of water vapour (A_{H_2O})is calculated using Equation (E.2).

$$A_{H_2O} = 1 - e^{\left(-k_{H_2O(t_a)} \times \left(p_{H_2O} \times D\right)^n\right)} \qquad \text{(E.2)}$$

where :

$k_{H_2O(t_a)}$ is the coefficient of the water vapour emission factor;

p_{H_2O} is the water vapour partial pressure in ambient air;

D is the average thickness of the radiating gas layer in m; and

t_a is the ambient air temperature in °C.

$$k_{H_2O(w)} = a_{H_2O} + b_{H_2O} \cdot \frac{t_a}{1000}$$

and the values for a_{H_2O}, b_{H_2O} and n are given by Expressions (E.3), (E.4) and (E.5) respectively.

$$a_{H_2O} = 0{,}062.(p_{H_2O} D)^{0{,}0283} \quad \text{(E.3)}$$

$$b_{H_2O} = 0{,}0038.\ln(p_{H_2O} D) - 0{,}0463 \quad \text{(E.4)}$$

$$n = 0{,}7032.(p_{H_2O} D)^{-0{,}0972} \quad \text{(E.5)}$$

where :

D is the mean thickness of the radiating gas layer in m.

The partial pressure of water vapour p_{H_2O} in kPa is given by Equation (E.6).

$$p_{H_2O} = 0{,}1.\frac{rh}{100}.6{,}1078.e^{\left(17{,}08.\frac{t_a}{234{,}175+t_a}\right)} \quad \text{(E.6)}$$

where :

rh is the relative humidity;

t_a is the ambient air temperature in °C.

E.4 Absorption of radiation by carbon dioxide

The emission factor of carbon dioxide A_{CO_2} is given by Equation (E.7).

$$A_{CO_2} = 1 - e^{\left[-k_{CO2(t_a)}.(p_{CO_2}.D)^n\right]} \quad \text{(E.7)}$$

where :

p_{CO_2} is the partial pressure of carbon dioxide in ambient air;

D is the average thickness of the radiating gas layer in m; and

$$k_{CO2(t_a)} = a_{CO_2} + b_{CO_2} \cdot \frac{t_a}{1000}$$

The values for a_{CO_2}, b_{CO_2} and n are given by Expressions (E.8), (E.9) and (E.10).

$$a_{CO_2} = 0{,}0532 \quad \text{(E.8)}$$

$$b_{CO_2} = 0{,}00168 \quad \text{(E.9)}$$

$$n = 0{,}527 \quad \text{(E10)}$$

The partial pressure of carbon dioxide p_{CO_2} is approximately equal to 0,03 kPa corresponding to a content of 300 ppm CO_2 in air.

E.5 Total radiation absorption

The total radiation absorption factor A_{TOT} for water vapour and carbon dioxide for a radiant output $Q_{(R)M}$ is given by Equation E.11.

$$A_{TOT} = A_{CO_2} + \beta \cdot A_{H_2O} \cdot (1 - A_{CO_2}) \quad \text{(E.11)}$$

where :

A_{CO_2} is the absorption factor of carbon dioxide;

A_{H_2O} is the absorption factor of water vapour; and

β is given by Equation E.12.

$$\beta = 1 + \left(0{,}76 - 0.0328\sqrt{p_{H_2O} \times D}\right)\frac{p_{H_2O}}{100} \quad \text{(E.12)}$$

Equation E.12 is valid for p_{H_2O} values between 0 kPa to 20 kPa and $\left(p_{H_2O} \times D\right)$ values between 0 kPa m to 1 kPa m.

E.6 Calculation method

The radiant output $Q_{(R)C}$ corrected for absorption by water vapour and carbon dioxide is calculated from the measured radiant output $Q_{(R)M}$ by Equation (8)

$$Q_{(R)C} = \frac{Q_{(R)M}}{1\text{-}A_{TOT}}$$

Annex F
(informative)

Radiant heat output data - Recording of results (Test method B)

F.1 General information to be recorded

F.1.1 Test and appliance data

Test Laboratory : ______________________________

Technician : ____________________ Test date : ____________________

Plaque heater : ____________________ Tube heater : ____________________

Equipment type : ____________________ Model : ____________________

Supplier : ____________________ Manufacturer : ____________________

Heater length : ____________________ m Heater width : ____________________ m

Nominal heat input : ____________________ kW Gas category : ____________________

Test gas net calorific value (H_i) at 15 °C and 1013,25 mbar : ____________________ kWh/m^3

F.1.2 Radiometer technical data

Radiometer name/number : ______________________________

Sensor type : ______________________________

Cooling system : ______________________________

Calibration certificate : ______________________________

Radiometer sensitivity (S) : ______________________________ $V/(W/m^2)$

Flush gas type : ____________________ Flush gas flow rate : ____________________ l/h

Sensor temperature : ____________________ °C Sensor temperature calibration : __________ °C

Chopper frequency : ____________________ Hz Amplifier supply voltage lock : __________ V

F.1.3 Measuring plane technical data

Number of measuring points (parallel with the longitudinal axis) : ____________________

Number of measuring points (perpendicular with the longitudinal axis) : ____________________

Measuring grid length : ____________________ m Measuring grid width : ____________________ m

Number of measuring cells : ____________________ Measuring cell area : ____________________ m^2

Measuring grid area : ____________________ m^2

Irradiance present in the outer lines smaller than 1 % of the maximum value : Yes/No

F.2 Measurement results

F.2.1 Test information

Parameter	Test number				
	1	2	3	4	5
Test date					
Test start time					
Test end time					

F.2.2 Test ambient conditions

Parameter	Test number				
	1	2	3	4	5
Air temperature at start (°C)					
Air temperature at end (°C)					
Ambient humidity at start (%)					
Ambient humidity at end (%)					
Atmospheric pressure (p_a) at start (mbar)					
Atmospheric pressure (p_a) at end (mbar)					

F.2.3 Gas/heat input data

Parameter	Test number				
	1	2	3	4	5
Gas category					
Wobbe index W_i (kWh/m³)					
Net calorific value H_i (kWh/m³)					
Gas flow (m³/h) at ambient conditions					
Gas temperature t_g (°C)					
Gas flow (m³/h) at 15 °C and 1013 mbar					
Heat input Q (kW)					
Heat input/nominal heat input Q/Q_n (%)					
Inlet gas pressure (mbar)					
Injector gas pressure (mbar)					
Relative pressure in burner chamber (mbar)					

F.2.4 Flue gas data

Parameter	Test number				
	1	2	3	4	5
CO_2 volume (%)					
CO (ppm)					
CO corrected (ppm)					
O_2 volume (%)					
Temperature (°C)					

F.2.5 Absorption of water vapour and CO_2 data

Parameter	Test number				
	1	2	3	4	5
Thickness of radiating gas layer $\overline{d}$ (m)					
Partial pressure of water vapour in ambient air pressure (kPa)					
Temperature t_w (°C) of the radiating surface NOTE 350 °C for Tube heater, 900 °C for Plaque heater					
Coefficient in equation for emission factor of water vapour k_{H_2O} (kPa^{-1} m^{-1})					
Emission factor of water vapour ε_{H_2O}					
Absorption factor of water vapour A_{H_2O}					
Emission factor of carbon dioxide ε_{CO_2}					
Absorption factor of carbon dioxide A_{CO_2}					
Surface area correction factor $C_{\alpha\beta}$					
Radiant correction factor for water vapour and CO_2 in air A_{TOT}					

F.2.6 Irradiation measurement data

Parameter	Test number				
	1	2	3	4	5
Sensor temperature (t_S) at start (°C)					
Sensor temperature (t_S) at end (°C)					
Measured radiant output ($Q_{(R)M}$) (W)					
Measured radiant output after correction for absorption $Q_{(R)C}$ (W)					
Radiant factor (R_f)					

Name :	
Signature:	

Annex G
(informative)

Worked example (Test method B)

G.1 General information

Test Laboratory : A

Technician : A | Test date : 14-04-04

Plaque heater : No | Tube heater : Yes

Equipment type : ______________________ | Model : A

Supplier : A | Manufacturer : A

Heater length : 5,24 m | Heater width : 0,49 m

Nominal heat input : 22 kW | Gas category : G 20

Test gas net calorific value (H_i) at 15 °C and 1013,25 mbar : 9,45 kWh/m^3

G.2 Radiometer technical data

Radiometer name/number : AA

Sensor type : Pyro-electrical detector

Cooling system : Water

Calibration certificate : 003/2004

Radiometer sensitivity (S) : 4,1339 x 10^{-4} V/(W/m^2)

Flush gas type : Nitrogen | Flush gas flow rate : 2 l/h

Sensor temperature : 22,6 °C | Sensor temperature calibration : 24,2 °C

Chopper frequency : 205 Hz | Amplifier supply voltage lock : ± 15 V

G.3 Measuring plane technical data

Number of measuring points (parallel with the longitudinal axis) : 54

Number of measuring points (perpendicular with the longitudinal axis) : 11

Measuring grid length : 5,3 m | Measuring grid width : 1,0 m

Number of measuring cells : 530 | Measuring cell area : 0,01 m^2

Measuring grid area : 5,3 m^2

Irradiance present in the outer lines smaller than 1 % of the maximum value : Yes/~~No~~

G.4 Measurement results

G.4.1 Test information

Parameter	Test number				
	1	2	3	4	5
Test date	14.04.04				
Test start time	12:43				
Test end time	14:07				

G.4.2 Test ambient conditions

Parameter	Test number				
	1	2	3	4	5
Air temperature at start (°C)	23,0				
Air temperature at end (°C)	24,5				
Ambient humidity at start (%)	24,0				
Ambient humidity at end (%)	23,2				
Atmospheric pressure (p_a) at start (mbar)	1024				
Atmospheric pressure (p_a) at end (mbar)	1020				

G.4.3 Gas/heat input data

Parameter	Test number				
	1	2	3	4	5
Gas category	G 20				
Wobbe index W_i (kWh/m³)	12,69				
Net calorific value H_i (kWh/m³)	9,45				
Gas flow (m³/h) at ambient conditions	1,98				
Gas temperature t_g (°C)	17,4				
Gas flow (m³/h) at 15 °C and 1013 mbar	2,04				
Heat input Q (kW)	19,26				
Heat input/nominal heat input Q/Q_n (%)	88				
Inlet gas pressure (mbar)	20				
Injector gas pressure (mbar)	10,57				
Relative pressure in burner chamber (mbar)	-1,4				

G.4.4 Flue gas data

Parameter	Test number				
	1	2	3	4	5
CO_2 volume (%)	5,6				
CO (ppm)	0				
CO corrected (ppm)	0				
O_2 volume (%)	11,2				
Temperature (°C)	185				

G.4.5 Absorption of water vapour and CO_2 data

Parameter	Test number				
	1	2	3	4	5
Thickness of radiating gas layer $\overline{d}$ (m)	0,99				
Partial pressure of water vapour in ambient air pressure (kPa)	0,71				
Temperature t_w (°C) of the radiating surface NOTE 350 °C for Tube heater, 900 °C for Plaque heater	350				
Coefficient in equation for emission factor of water vapour k_{H_2O} (kPa^{-1} m^{-1})	0,0460				
Emission factor of water vapour ε_{H_2O}	0,0579				
Absorption factor of water vapour A_{H_2O}	0,0415				
Emission factor of carbon dioxide ε_{CO_2}	0,0121				
Absorption factor of carbon dioxide A_{CO_2}	0,0075				
Surface area correction factor $C_{\alpha\beta}$	1,0107				
Radiant correction factor for water vapour and CO2 in air A_{TOT}	0,0491				

G.4.6 Irradiation measurement data

Parameter	Test number				
	1	2	3	4	5
Sensor temperature (t_S) at start (°C)	22,0				
Sensor temperature (t_S) at end (°C)	22,1				
Measured radiant output ($Q_{(R)M}$) (W)	9578				
Measured radiant output after correction for absorption $Q_{(R)C}$ (W)	10072				
Radiant factor (R_f)	0,52				

Name :	
Signature:	

Measurement data (V)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.010	0.030	0.050	0.040	0.030	0.050	0.040	0.030	0.040	0.050	0.050	0.040	0.030	0.050	0.020
3	0.000	0.000	0.000	0.080	0.230	0.280	0.320	0.360	0.330	0.300	0.280	0.280	0.270	0.280	0.280	0.270	0.270	0.270	0.270	0.220
4	0.000	0.000	0.000	0.250	0.590	0.750	0.810	0.850	0.860	0.810	0.740	0.850	0.870	0.910	0.940	0.930	0.940	0.940	0.940	0.940
5	0.000	0.000	0.000	0.350	0.830	0.910	0.960	0.990	1.020	1.020	0.940	1.080	1.130	1.180	1.230	1.260	1.270	1.290	1.320	1.370
6	0.000	0.000	0.000	0.340	0.890	0.900	0.910	0.970	1.020	1.000	0.990	1.160	1.230	1.280	1.330	1.410	1.430	1.480	1.560	1.640
7	0.000	0.000	0.000	0.290	0.690	0.820	0.920	0.990	1.090	1.110	1.100	1.360	1.420	1.510	1.600	1.710	1.810	1.880	1.980	2.100
8	0.000	0.000	0.000	0.160	0.420	0.560	0.620	0.670	0.730	0.740	0.770	0.990	1.080	1.170	1.240	1.350	1.430	1.510	1.570	1.640
9	0.000	0.000	0.000	0.000	0.020	0.080	0.110	0.110	0.130	0.110	0.160	0.170	0.220	0.220	0.250	0.300	0.300	0.350	0.400	0.430
10	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010	0.030	0.020	0.020	0.040	0.060	0.040	0.080	0.070	0.090	0.110	0.110	0.120
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000
2	0.010	0.020	0.020	0.030	0.010	0.010	0.040	0.020	0.030	0.070	0.060	0.050	0.060	0.090	0.070	0.040	0.040	0.040	0.050	0.040
3	0.290	0.300	0.280	0.230	0.250	0.250	0.290	0.280	0.270	0.310	0.340	0.330	0.350	0.360	0.370	0.310	0.340	0.300	0.290	0.310
4	0.990	1.010	0.970	0.950	0.910	0.900	0.910	0.910	0.930	0.960	0.970	0.980	1.010	1.010	1.010	0.950	0.980	1.010	1.010	1.040
5	1.440	1.460	1.440	1.380	1.310	1.260	1.260	1.280	1.300	1.330	1.320	1.380	1.430	1.460	1.500	1.480	1.530	1.590	1.640	1.680
6	1.720	1.740	1.740	1.640	1.500	1.480	1.490	1.530	1.570	1.560	1.570	1.640	1.700	1.730	1.760	1.790	1.820	1.920	1.980	2.030
7	2.120	2.140	2.180	2.050	1.810	1.780	1.810	1.840	1.920	1.940	1.970	2.050	2.110	2.180	2.240	2.320	2.350	2.480	2.580	2.650
8	1.670	1.710	1.760	1.670	1.500	1.450	1.460	1.480	1.550	1.560	1.560	1.660	1.710	1.800	1.860	1.960	2.000	2.120	2.210	2.310
9	0.490	0.500	0.580	0.560	0.520	0.570	0.570	0.560	0.580	0.570	0.570	0.590	0.570	0.570	0.600	0.580	0.610	0.590	0.650	0.630
10	0.130	0.150	0.150	0.130	0.120	0.130	0.150	0.140	0.140	0.140	0.140	0.170	0.160	0.190	0.190	0.190	0.200	0.220	0.210	0.230
11	0.010	0.050	0.040	0.030	0.040	0.050	0.040	0.050	0.030	0.060	0.060	0.080	0.070	0.070	0.090	0.060	0.080	0.080	0.080	0.050

	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1	0.000	0.000	0.000	0.000	0.000	0.020	0.020	0.020	0.030	0.030	0.020	0.000	0.000	0.000
2	0.010	0.010	0.010	0.030	0.060	0.100	0.100	0.110	0.110	0.080	0.050	0.010	0.000	0.000
3	0.190	0.180	0.220	0.210	0.310	0.350	0.380	0.390	0.410	0.360	0.230	0.090	0.020	0.000
4	0.990	1.010	1.050	1.080	1.120	1.160	1.190	1.180	1.140	0.980	0.560	0.240	0.120	0.000
5	1.680	1.710	1.770	1.820	1.850	1.840	1.800	1.750	1.620	1.350	0.800	0.330	0.200	0.010
6	2.100	2.130	2.230	2.300	2.330	2.310	2.230	2.160	1.980	1.570	0.920	0.320	0.110	0.000
7	2.790	2.840	2.990	3.050	3.080	3.010	2.880	2.750	2.490	1.910	1.000	0.340	0.060	0.000
8	2.500	2.520	2.640	2.680	2.610	2.510	2.320	2.240	1.980	1.510	0.780	0.250	0.020	0.000
9	0.670	0.700	0.750	0.760	0.690	0.700	0.610	0.620	0.530	0.400	0.230	0.070	0.000	0.000
10	0.210	0.210	0.230	0.230	0.230	0.210	0.180	0.190	0.150	0.130	0.080	0.020	0.000	0.000
11	0.040	0.050	0.050	0.050	0.040	0.030	0.040	0.030	0.040	0.020	0.000	0.000	0.000	0.000

Measured radiant output in W ($E_{ij} \times F_{ij}$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.06	0.24	0.73	0.79	0.42	0.48	0.54	0.42	0.42	0.60	0.67	0.54	0.42	0.48	0.42	0.18
2	0.00	0.00	0.48	1.87	3.14	3.87	4.60	4.72	4.23	3.99	3.93	3.75	3.75	3.93	3.93	3.81	3.69	3.75	3.39	3.27
3	0.00	0.00	2.00	6.95	11.19	13.06	14.15	14.51	13.91	12.88	13.00	13.73	14.09	14.57	14.63	14.57	14.63	14.63	14.33	14.76
4	0.00	0.00	3.63	12.22	18.63	20.74	21.83	22.50	22.44	21.23	21.83	23.77	24.73	25.76	26.37	26.61	26.85	27.15	27.64	28.67
5	0.00	0.00	4.17	14.57	21.35	22.25	23.16	24.19	24.55	23.89	25.22	27.82	29.15	30.36	31.63	32.48	33.08	34.17	35.62	37.31
6	0.00	0.00	3.81	13.36	19.96	21.47	22.92	24.61	25.52	25.40	27.88	31.27	32.90	34.59	36.59	38.46	39.91	41.73	44.03	45.84
7	0.00	0.00	2.72	9.43	15.06	17.66	19.35	21.05	22.19	22.50	25.52	29.33	31.33	33.38	35.68	38.10	40.09	41.97	44.09	45.54
8	0.00	0.00	0.97	3.63	6.53	8.29	9.13	9.92	10.34	10.76	12.64	14.88	16.27	17.42	18.99	20.44	21.71	23.16	24.43	25.58
9	0.00	0.00	0.00	0.12	0.60	1.15	1.33	1.45	1.45	1.63	2.00	2.36	2.66	2.84	3.33	3.63	3.93	4.60	5.14	5.68
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.12	0.12
Sum	0.00	0.00	17.8	62.2	96.5	108.7	117.2	123.7	125.1	122.8	132.6	147.3	155.3	163.5	171.8	178.6	184.3	191.7	199.2	206.9

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	0.18	0.24	0.30	0.24	0.12	0.30	0.36	0.30	0.67	0.85	0.67	0.67	1.03	1.09	0.67	0.48	0.48	0.54	0.54	0.30
2	3.75	3.75	3.39	3.14	3.14	3.57	3.81	3.63	4.11	4.72	4.72	4.78	5.20	5.38	4.78	4.41	4.35	4.11	4.17	3.33
3	15.66	15.48	14.70	14.15	13.97	14.21	14.45	14.45	14.94	15.60	15.84	16.15	16.51	16.63	15.97	15.60	15.90	15.78	16.03	15.30
4	29.63	29.51	28.67	27.52	26.49	26.19	26.37	26.73	27.33	27.70	28.12	29.03	29.69	30.12	29.87	29.87	30.90	31.75	32.48	32.60
5	38.46	38.58	37.49	35.26	33.56	33.20	33.62	34.35	34.83	34.95	35.74	37.19	38.22	39.01	39.49	40.03	41.49	43.12	44.33	45.30
6	46.69	47.17	46.02	42.33	39.73	39.67	40.34	41.49	42.27	42.57	43.72	45.36	46.69	47.84	49.05	50.07	51.83	54.19	55.88	57.87
7	46.20	47.11	46.32	42.51	39.55	39.31	39.85	41.06	42.15	42.51	43.78	45.54	47.17	48.86	50.68	52.19	54.13	56.79	58.96	61.99
8	26.43	27.52	27.64	25.70	24.43	24.49	24.61	25.22	25.76	25.76	26.49	27.40	28.12	29.21	30.24	31.14	32.17	33.68	35.08	36.95
9	6.35	7.08	7.32	6.95	7.14	7.44	7.38	7.38	7.50	7.62	7.86	7.92	7.74	8.04	8.04	8.04	8.22	8.47	8.53	8.41
10	0.36	0.54	0.42	0.42	0.54	0.54	0.54	0.48	0.54	0.73	0.85	0.91	0.85	0.97	0.91	0.85	0.97	0.97	0.79	0.54
Sum	213.7	217.0	212.3	198.2	188.7	188.9	191.3	195.1	200.1	203.0	207.8	214.9	221.2	227.1	229.7	232.7	240.4	249.4	256.8	262.6

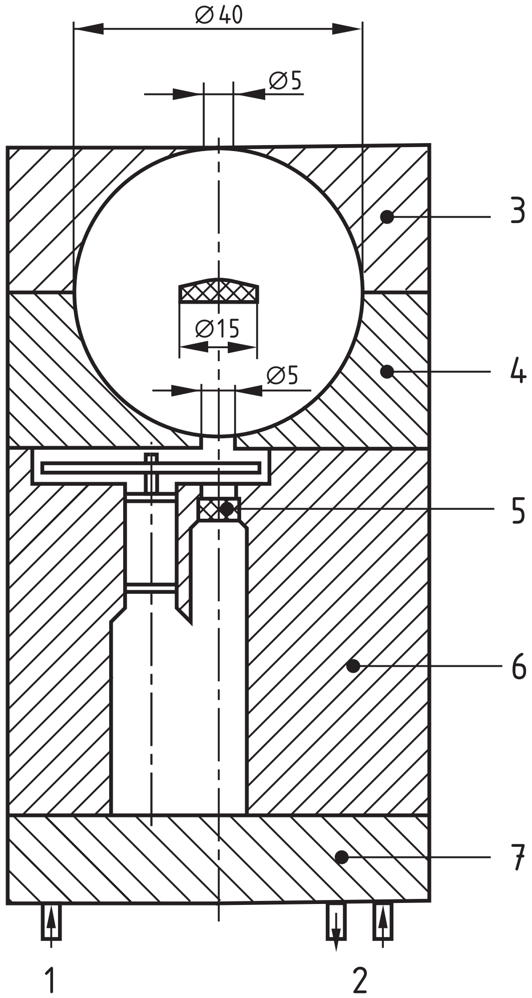
	41	42	43	44	45	46	47	48	49	50	51	52	53	Measured radiant output in W
1	0.12	0.12	0.24	0.54	1.09	1.45	1.51	1.63	1.51	1.09	0.48	0.06	0.00	
2	2.36	2.54	2.84	3.69	4.96	5.62	5.93	6.17	5.81	4.35	2.30	0.73	0.12	
3	14.33	14.88	15.48	16.45	17.78	18.63	18.99	18.87	17.48	12.88	6.77	2.84	0.85	
4	32.60	33.50	34.59	35.50	36.10	36.22	35.80	34.41	30.78	22.32	11.67	5.38	2.00	
5	46.08	47.41	49.11	50.19	50.38	49.47	48.02	45.42	39.43	28.06	14.33	5.81	1.94	
6	59.63	61.62	63.92	65.07	64.89	63.08	60.60	56.73	48.08	32.66	15.60	5.02	1.03	
7	64.41	66.46	68.70	69.06	67.79	64.83	61.62	57.21	47.71	31.45	14.33	4.05	0.48	
8	38.64	39.97	41.30	40.76	39.37	37.13	35.02	32.48	26.73	17.66	8.04	2.06	0.12	
9	8.83	9.37	9.74	9.31	8.83	8.35	7.86	7.38	5.99	3.93	1.81	0.42	0.00	
10	0.54	0.60	0.60	0.54	0.42	0.42	0.42	0.42	0.36	0.12	0.00	0.00	0.00	
Sum	267.5	276.5	286.5	291.1	291.6	285.2	275.8	260.7	223.9	154.5	75.35	26.37	6.53	9578.00

Annex H
(informative)

Radiometer design (Test method B)

H.1 Principle radiometer design features

The principle design features of the radiometer are shown in Figure H.1.



Key

1 Nitrogen purge
2 Water inlet and outlet for cooling
3 Plate I (water cooled)
4 Plate II
5 Pyroelectric detector
6 Plate III
7 Plate IV

Figure H.1 — Radiometer design features

The radiation enters the radiometer through the upper orifice (in plate I) and is reflected several times on the inner surface of the integrating sphere. The radiation is collected by the pyro-electric detector. To avoid direct radiation being received by the detector, a horizontal, gold-plated disc is installed in the centre of the integrating sphere. The upper orifice has sharp edges and the sphere is internally gold-coated so as to produce diffuse reflection (thickness of the gold layer 5 µm to 10 µm) of the infrared radiation. The radiation received by the pyro-electric detector is interrupted periodically by a chopper wheel. The output of the detector is controlled electronically in order to achieve a continuous signal of between 0 V and 10 V.

H.2 Radiometer technical design

Figure H.1 shows a suitable design for the radiometer. This consists of four brass plate screwed together to a unit.

The radiometer is required to be cooled by water to protect the electronics, the detector and the chopper. The temperature of these parts need to be maintained at (25 ± 2) °C. The temperature of the cooling water should be controlled to avoid excess cooling or heating. A thermometer (e.g. PT-100) is installed for the purpose of temperature control.

The internal parts should be vented continuously with dry nitrogen at a flow rate of about 2 l/h, in order to avoid the ingress of combustion products, dust etc.

The frequency with which the chopper wheel interrupts the interruption of the radiation should be adjusted in such a way as to avoid multiples of 50. This is necessary for correct operation of the amplifier given the frequency of the electrical mains supply.

H.3 Pyro-electric detector

It is recommended to use a pyro-electric detector (e.g. LiTaO3) together with an adequate window for transmission of the radiation (e. g. a window made of KBr with a protective layer) with a spectral range of 0,8 µm to 40 µm. The pyro-electric detector is used in the voltage mode. In this mode, the sensitivity of the detector depends on the frequency of the chopper wheel. Normally the detector can be used in a frequency range between 30 Hz to 4 kHz with a positive polarity (the positive signal output increases with the irradiance). The installation and use of the detector shall be in accordance with the manufacturer’s instructions. All electrical wiring should be protected from external EMC-influences.

The sensitivity of the detector can be changed by the frequency of the chopper wheel. Due to the influence of the frequency of the chopper wheel on the output signal, the frequency should be kept as constant as possible.

Annex I
(normative)

Radiometer calibration (Test method B)

I.1 Radiometer calibration

I.1.1 General

Calibration of the radiometer shall be achieved against a so-called “black body”. The irradiance inside the black body (W/m²) is compared with the output signal (V). The calibration curve is a straight line through the point of origin in the coordinate system showing the output signal (V) as a function of the irradiance (see Figure I.1). For the calibration, the radiometer shall be operated in the same mode as that used for measuring the radiation under the heater, utilising the same wiring, amplifier and other components used.

I.1.2 Black Body calibration method

This method utilizes a black body with a spherical cavity made of ceramic material having an internal diameter of 300 mm that can be heated at least to a temperature of 600 °C. The spherical cavity has an opening (aperture) of the same diameter as the radiometer to be calibrated.

For the calibration the radiometer is inserted through the aperture in the spherical cavity into the black body, so that the front surface of the radiometer is aligned with the internal spherical cavity surface. Irradiance from the internal hot surface of the black body is transmitted to the radiometer and provides an adequate output signal (V).

Calibration up to a black body temperature of 600 °C is sufficient.

NOTE A black body ($\varepsilon \cong 1$) with a temperature of 600°C gives the same irradiance as a luminous radiant heater ($\varepsilon<1$) with a temperature of 900 °C.

The irradiance *E* (W/m²) at a temperature of *T* (K), referred to a radiometer temperature of 20 °C, is calculated using the Stephan-Boltzmann-formula shown in Equation (I.1).

$$E = \sigma \left(T^4 - 293^4\right) \qquad \text{(I.1)}$$

where :

σ = 5,67 x 10^{-8} in W/(m^2T^4)

The sensitivity at each temperature is calculated using Equation (I.2).

$$\frac{1}{S} = \frac{E}{U} \text{ in (W/m}^2\text{)/V} \qquad \text{(I.2)}$$

where :

S is the radiometer sensitivity in μV/(W/m^2);

U is the sensor voltage in V;

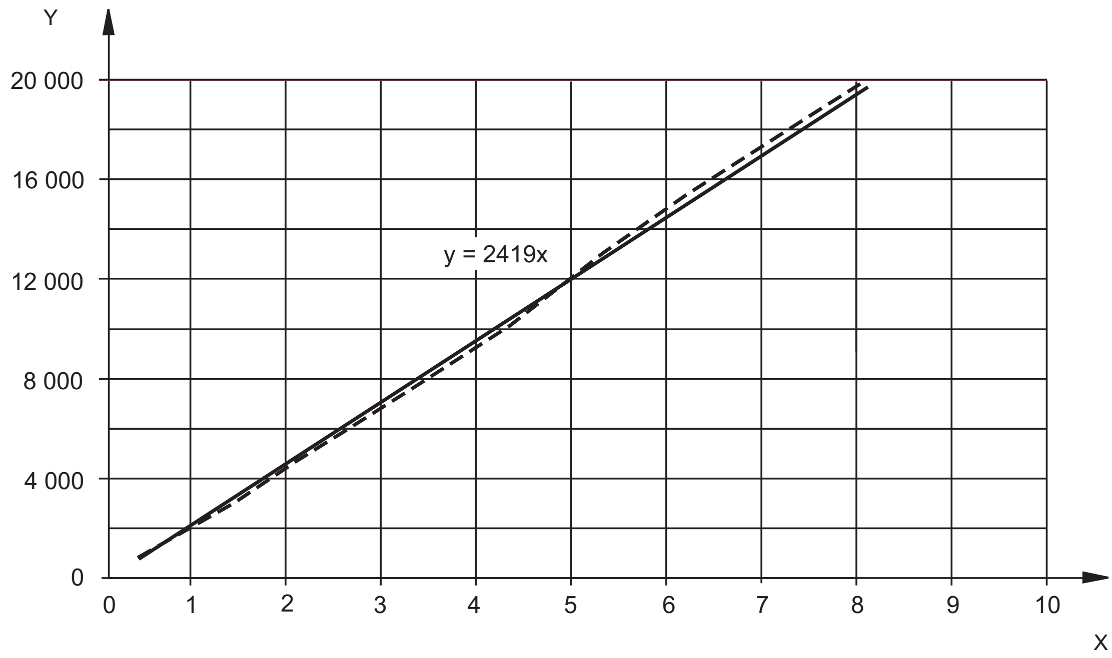
The calibration shall be carried out over the whole range of irradiances of the luminous radiant heater (or tube heater). This is achieved by calibration at several temperatures of the black body. For every temperature, the measurements shall be carried out at least three times and the average of the values calculated. Thermal equilibrium shall be achieved at each of the measurement temperatures prior to taking the measurements. The sensitivity for the whole range of irradiances is determined from these individual sensitivities by using graphical methods and statistical means. The irradiance is plotted against the voltage output of the radiometer (see Figure I.1). The correlation factor is given by the best fitted, straight line, through the point of origin (see I.2).

The calibration shall be carried out for irradiances up to at least 2,0 x 10^4 W/m^2.

I.2 Worked example

Table I.1 — Tube heater calibration

Black body temperature (°C)	Average output signal (V)	Irradiance (W/m²)	1/Sensitivity S ((W/m²)/V)
100	0,299	680	2273
150	0,573	1398	2439
202	0,990	2469	2491
250	1,557	3825	2456
300	2,487	5695	2290
352	3,605	8235	2284
402	4,776	11354	2377
452	6,284	15249	2427
500	8,037	19828	2467



Key

x Average output signal (V)

y Irradiance (W/m^2)

Figure I.1 — Determination of the correlation factor for a luminous radiant heater

According to the graph and using Equation (I.2):

$$S = \frac{1}{2419} = 4,1339 \times 10^{-4} \text{ in } (\text{W/m}^2)/\text{V}$$

Annex ZA
(informative)

Clauses of this European Standard addressing essential requirements or other provisions of EU directives

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to essential requirements of the EU Directive 90/396/EEC on the approximation of the laws of Member States concerning gas appliances.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1

Essential requirement	Subject	Requirements of the standard	Comment
3.5	Rational use of energy	1 2 3 4 6	

WARNING: Other requirements and other EU Directives *may* be applicable to the products falling within the scope of this standard.

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