JOINT CANADA - UNITED STATES
NATIONAL STANDARD

CAN/ANSI/AHRI 1330-2015, *Performance Rating for Radiant Output of Gas Fired Infrared Heaters*

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Prepared by:

we make life better®

Approved by:

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This is a new standard.

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PERFORMANCE RATING STANDARD FOR RADIANT OUTPUT OF GAS FIRED INFRARED HEATERS

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish for infrared heaters: definitions; test requirements; rating requirements; nomenclature; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

1.1.1 *Intent*. This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 *Review and Amendment*. This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope.* This standard applies to Infrared Heaters that are Gas-Fired High-intensity Infrared Heaters and Gas-Fired Low-intensity Infrared Heaters with inputs up to and including 117.5 kW per burner intended for installation in and heating of outdoor or indoor spaces.

2.1.1 *Exclusions.* This standard does not apply to heaters that do not radiate their energy into a single measuring plane.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the ASHRAE Terminology website (https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

3.1 *Calibration Factor.* The results of the calibration provided by an ISO 17025 accredited testing/calibration laboratory in the form of a calibration factor consisting of a constant (a) and offset (b).

3.2 *Gross Radiant Coefficient.* Heat emitted by the appliance through the radiation reference plane divided by the gross heat input of the test gas.

3.3 *Infrared Factor.* A performance rating factor based on the gross radiant coefficient. Refer to Table 1.

3.4 *Infrared Heater.* A heater which directs a substantial amount of its energy output in the form of infrared energy into the area to be heated. Such heaters may be of either the vented or unvented type. The following are types of infrared heaters.

3.4.1 *High-intensity Infrared Heater.* An infrared heater which has a radiating surface that typically operates at or above 732.0ºC.

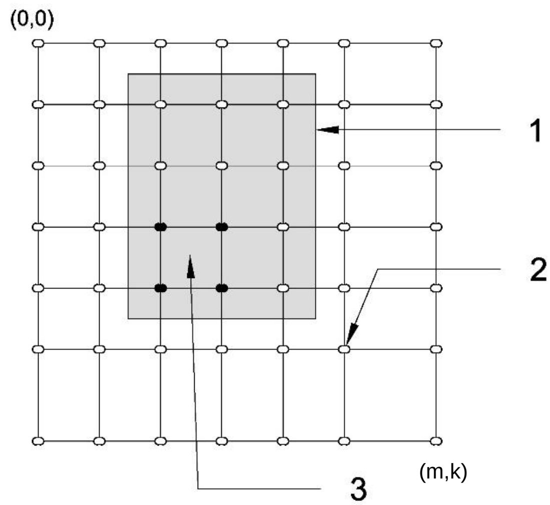
3.4.2 *Low-intensity Infrared Heater*. An infrared heater which has a radiating surface that typically operates at temperature less than 732.0ºC.

3.4.2.1 *Radiant Tube Infrared Heater*. Typically, a low intensity infrared heater in which combustion takes place within a tube or conduit.

3.5 *Measuring Cell*. A measuring cell is defined as the area contained by four (4) adjacent nodal points of a measuring grid.

3.6 *Measuring Plane.* A plane parallel and below the radiation reference plane.

3.7 *Measuring Grid.* Regular arrangement in the measuring plane of straight lines running parallel and perpendicular to the longitudinal axis of the appliance.



1 Heater
2 Nodal Point
3 Measuring Cell Fij

Figure 1. Measuring Grid

3.8 *Minimum Angle*. The minimum installation angle specified by the manufacturer. The minimum angle is measured from the horizontal plane.

3.9 *Nodal Point/Node.* A nodal point or node is the intersection of the perpendicular and parallel grid lines on the measuring plane, where an individual measurement is recorded. Four (4) adjacent nodal points confine a measuring cell.

3.10 *Published Rating.* A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to the model tested and identical models produced by the same manufacturer under different model numbers. The term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.10.1 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

3.11 *Radiation Reference Plane.* Flat 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 surface touching the lowest radiant part (refer to Figure 2).

3.12 *Rating Conditions.* Any set of operating conditions under which a single level of performance results.

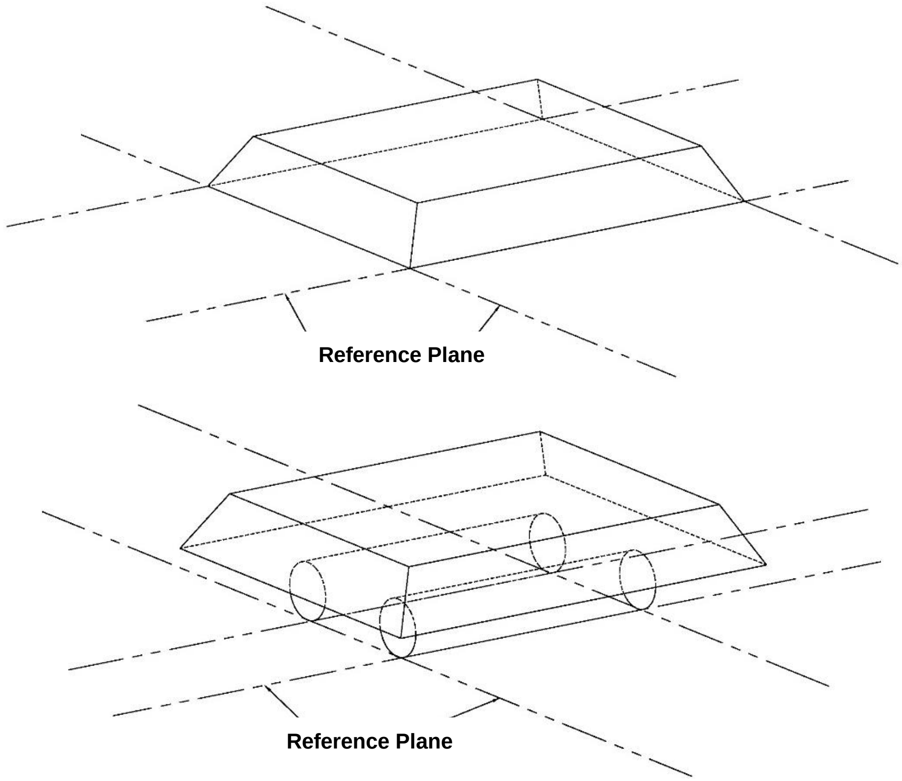


Figure 2. – Radiation Reference Plane

3.12.1 *Standard Rating Conditions.* Rating Conditions used as the basis of comparison for performance characteristics.

3.13 *"Shall" or "Should".* "Shall" or "should" shall be interpreted as follows:

3.13.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.13.2 *Should.* "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

Section 4. Test Requirements

4.1 *Test Requirements.* Published Ratings shall be verified by tests conducted in accordance with the test method described in Appendix C and in accordance with the rating requirements of Section 5.

Section 5. Rating Requirements

5.1 *Rating Requirements.* The Infrared Factor shall be established by using Table 1.

5.2 *Standard Ratings.* Standard Ratings shall be established at the operating conditions specified in Section C4. All Standard Ratings shall be verified by tests in accordance with Appendix C.

5.3 *Tolerances.* If the Gross Radiant Coefficient falls within ±0.005 of the ranges shown in Table 1, the rating shall be determined by the average of 3 sequential tests or by selecting the next lower Infrared Factor. The published rating shall not exceed the Infrared Factor calculated in accordance with Appendix C.

Table 1. Rating Requirements

Gross Radiant Coefficient	Infrared Factor (IF)
≤ .35	7
> .35 ≤ .40	8
> .40 ≤ .45	9
> .45 ≤ .50	10
> .50 ≤ .55	11
> .55 ≤ .60	12
> .60 ≤ .65	13
> .65 ≤ .7	14
> 0.7	15

Section 6. Nomenclature

Table 2. Nomenclature

Symbol	Title	Unit
a	Constant	—
a_{CO_2}	Coefficient in equation for $k_{CO_2(t_a)}$	$kPa^{-1}\ m^{-1}$
a_{H_2O}	Coefficient in equation for $K_{H_2O(t_a)}$	$kPa^{-1}\ m^{-1}$
A_{CO_2}	Absorption factor of carbon dioxide	—
A_{H_2O}	Absorption factor of water vapor	—
A_{TOT}	Total Radiant correction factor for water vapor and CO_2 in air	—
β	Partial pressure factor	—
b	Signal offset	—
b_{CO_2}	Coefficient in equation for $k_{CO_2(t_a)}$	$kPa^{-1}m^{-1}°C^{-1}$
b_{H_2O}	Coefficient in equation for $K_{H_2O(t_a)}$	$kPa^{-1}m^{-1}°C^{-1}$
D	Thickness of Radiation Gas Layer.	m
E_{if}	Average irradiance over the measuring cell	kW/m^2
F_{if}	Area of measuring cell	m^2
H_s	Gross calorific value of the test gas (at 15 °C, 1013.25 mbar, dry gas)	kWh/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 vapor	$kPa^{-1}\ m^{-1}$
L	Length of the radiating surface of the heater	m
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 vapor in ambient air	kPa
p	Gas supply pressure	mbar
p_a	Atmospheric pressure	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
$Q_{(R)M}$	Radiant output	W
R	Minimum distance between the radiometer and the radiation reference plane	m
R_f	Radiant factor	—
r_h	Relative humidity	%
t_a	Average ambient air temperature	°C
t_g	Gas temperature at measuring point	°C
U	Sensor voltage	V
U_{if}	Average sensor voltage	V
U_{ij}	Average sensor voltage	V
V	Gas volume input at test conditions	m^3/h
V_o	Gas volume rate under reference conditions (at 15 °C, 1013.25 mbar, dry gas)	m^3/h
y	Radiant intensity	kW/m^2

Section 7. Minimum Data Requirements for Published Ratings

7.1 *Minimum Data Requirements for Published Ratings*. As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 1330". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of AHRI Standard 1330". Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

The following shall be reported for each appropriate model(s):

- Model Number
- Heat Input, kW
- Length of Heat Exchanger Tube including length of U-bends and elbows measured through the center-line (Radiant Tube Infrared Heaters only), m
- Infrared Factor
- Minimum angle. shall be specified if it is not tested in a horizontal position, Deg

Section 8. Marking and Nameplate Data

8.1 *Marking and Nameplate Data*. As a minimum, the appliance shall display the manufacturer's name, model number, IR factor, heat input, and minimum angle. This information may be provided on multiple markings, if required.

8.1.1 *Radiant Tube Infrared Heaters.* For Radiant Tube Infrared Heaters, the appliance shall also display the configuration (straight or U-tube), and heat exchanger length.

Section 9. Conformance Conditions

9.1 *Conformance*. While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES – NORMATIVE

A1 Listed here are all standards, handbooks, and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of this standard.

A1.1 *ASHRAE Terminology*, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2014, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.2 BS EN 416-2:2006, *Single burner gas-fired overhead radiant tube heaters for non-domestic use*, 2006, European Committee for Standardization, Rue De Stassart 36 B-1050 Brussels, Belgium.

A1.3 BS EN 419-2:2006, *Non-domestic gas-fired overhead luminous radiant heaters Rational use of energy*, 2006, European Committee for Standardization, Rue De Stassart 36 B-1050 Brussels, Belgium.

A1.4 ISO 17025:2005, *General requirements for the competence of testing and calibration laboratories*, 2005, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

APPENDIX B. REFERENCES – INFORMATIVE

B1 Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

None.

APPENDIX C. METHODS OF TESTING FOR RATING INFRARED HEATERS– NORMATIVE

C1 *Purpose*. The purpose of this appendix is to provide a method of testing for Infrared Heaters.

C2 *Scope.* Refer to Section 2 of the standard.

C3 *Test Equipment.*

C3.1 *Radiometer Equipment.* The radiometer designed in conjunction with the method of test (Method B) EN 416-2 and EN 419-2 shall be used. Appendix D provides a source.

Note: Additional information on radiometer equipment may be obtained from Appendix E.

C3.1.1 *Chopper Frequency.* The chopper frequency, with which the chopper wheel interrupts the reception of the radiation, shall be adjusted to match the calibration frequency of the radiometer. It shall remain constant during the test. The chopper frequency shall avoid the same frequency as the electrical supply frequency to the data acquisition equipment, for example, 50Hz or 60Hz.

C3.1.2 *Radiometer Insulation.* A round radiation shield of insulating material with an outer diameter of 300 mm shall be placed flush to the head of the radiometer. The radiation shield shall be a minimum of 5 mm thick with a thermal conductivity < 0.05 W/m-K.

C3.1.2 *Radiometer Calibration.* The radiometer shall be calibrated by an ISO 17025:2005 accredited testing/calibration laboratory. Note the calibration procedure is described in Appendix E, Section E6 for reference.

Note: The calibration procedure is described in Appendix E, Section E6 for reference.

C3.1.2.1 *Validity of Radiometer Calibration.* The calibration shall be approved, if:

C3.1.2.1.1 The time interval between measurement and the date of calibration is less than 3 months; or

C3.1.2.1.2 The accredited testing/calibration laboratory will provide the results of the calibration in the form of a calibration factor consisting of a constant (a) and offset (b); or

C3.1.2.1.3 There is evidence that the change in radiant output $Q_{(R)M}$ (W) or voltage (V) shall not deviate more than 4% for a known radiant heat source. The irradiance of a non-adjustable controlled radiant heat source shall be immediately benchmarked following the radiometer calibration.

C3.2 *Mechanical Test Equipment.* Test equipment shall:

C3.2.1 If it is mechanical equipment, enable the appliance to be suspended horizontally or at the minimum angle in accordance with the requirements of manufacturer.

C3.2.2 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.

C3.2.3 The radiometer shall be mounted from the base.

C3.3 *Radiometer Measurement Positions.* The irradiance measurement positions shall be established as below.

C3.3.1 *Measuring Plane.* The radiometer shall be setup such that the measuring plane is 100mm ±3mm below the radiation reference plane (see Figure C1 through Figure C4).

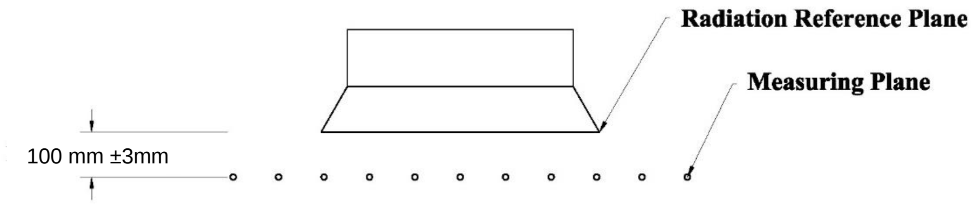


Figure C1. Radiation Reference Plane and Measuring Plane of a Horizontally Mounted High Intensity Infrared Heater

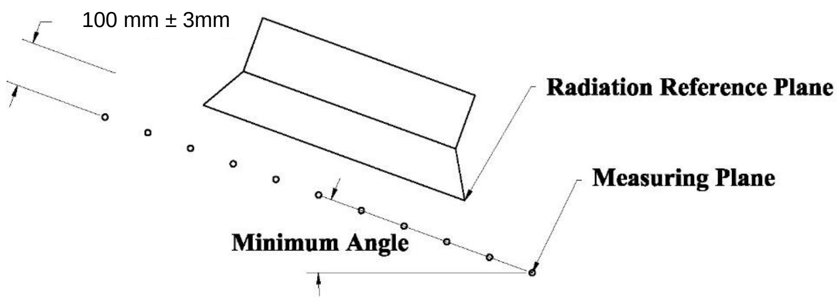


Figure C2. Radiation Reference Plane and Measuring Plane of an Angle Mounted High Intensity Infrared Heater.

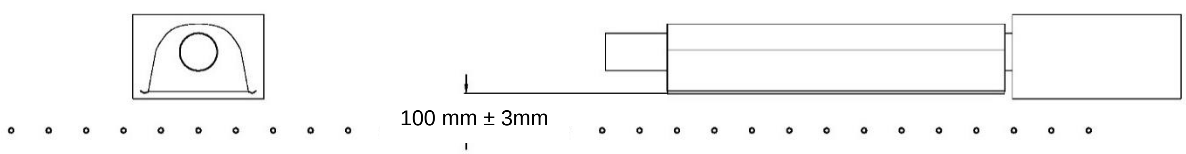


Figure C3. Measuring Plane of a Horizontally Mounted Low Intensity Infrared Heater

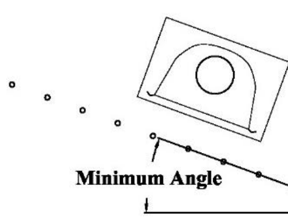


Figure C4. Measuring Plane of an Angle Mounted Low Intensity Infrared Heater

C3.3.2 *Measuring Grid.* Nodal points of the measuring grid are located at the intersection of the perpendicular and parallel grid lines such that the distance between all adjacent node points on these lines is 100 mm ± 2 mm. The cell size may vary based on the physical dimensions of the heater, however the cell dimensions shall remain equal, and the tolerance shall be constant for all cell sizes at ± 2 mm. for e.g. 50 ± 2 mm.

C3.3.2.1 *Establishing End Points of a Measuring Grid.* The measuring grid in the measuring plane shall be established in the following manner:

C3.3.2.1.1 Establish the center line of the reference plane.
C3.3.2.1.2 Locate a series of node points equally spaced along the center line.
C3.3.2.1.3 Expand the measuring grid perpendicular to the center line locating additional node points until the measurement is less than 1% of the maximum measured irradiance under the appliance.
C3.3.2.1.4 Establish additional node points longitudinally along the center line of the heater locating additional node points until the measurement is less than 1% of the maximum measured irradiance under the appliance.
C3.3.2.1.5 The (0,0) nodal point is located at one corner of the measurement grid.

C3.4 *Test Equipment Tolerance.* See Table C1.

Table C1. Equipment Precision and Accuracy Requirements

Item	Instrument accuracy	Instrument precision[1]
Atmospheric pressure	± 0.34 kPa	± 0.17 kPa
Air temperature	± 0.5°C	± 0.25°C
Relative Humidity	± 1% R.H.	0.5% R.H.
Gas flow	± 1% of reading	0.014 m^3
Heating value of fuel	± 1% of reading	0.0745 MJ/m^3
Time	± 0.5 s/h	0.25 s/h
Nitrogen Flow	± 10 L/h	2.5 L/h

Note: 1. The smallest scale division on an instrument used shall not be more than twice the specified precision.

C4 *Test Requirements and Operating Conditions.*

C4.1 *General.* The test shall be carried out with the appliance mounted horizontally in accordance with the manufacturer's instructions, or if the appliance is not intended to mount horizontally then the test shall be carried out at the minimum mounting angle from the horizontal. The appliance shall be suspended at least 1.2 m above the floor. Vented infrared heaters shall be set up with the minimum vent length and venting system specified in the manufacturer's installation instructions.

C4.2 *Working Area.* The test shall be carried out in a working area having a floor with a non-metallic surface. The working area shall be of a size to allow installation of the appliance and shall:

C4.2.1 Provide sufficient ventilation to remove the combustion products and heat generated by the appliance
C4.2.2 Have an ambient air temperature of 20 ± 5°C measured outside the direct radiation from the Infrared Heater being tested
C4.2.3 Have an airflow around the temperature and relative humidity sensors shall be less than 0.25 m/s.

C4.3 *Thermal Equilibrium of the Radiometer*. The temperature of the sensor shall be determined during the entire measurement period and recorded at each measurement point. Adjust the temperature of the coolant water through the probe to maintain a sensor temperature within the range of 20°C ± 0.75°C during the measurement period.

C4.4 *Nitrogen Purging of the Radiometer.* Dry nitrogen at a flow rate of 50 ± 25 L/h shall be used to purge the radiometer probe during all of the test.

C4.5 *Steady State Conditions.* The Infrared Heater shall be operated until the heater attains the steady state condition as defined by the manufacturer. If not defined by the manufacturer, the infrared heater shall be operated for a minimum period of 30 minutes.

C4.6 *Heat Input.* The appliance shall be tested with natural gas unless approved for propane gas use only. Determine the actual higher heating value in kWh/m^3 for the gas to be used in the test with an error no greater than ±1%. Heat input (Q_m) shall be adjusted to be ±2% of the nameplate rating. In conducting the performance test specified herein, gases with characteristics approximately as shown in Table C2 shall be used.

Table C2. Fuel Values

Fuel Type	Heating Values, Hs	Specific Gravity
Natural Gas	11.14 kWh/m^3	0.65
Propane Gas	25.86 kWh/m^3	1.53

C5 *Test Procedure.*

C5.1 *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.

C5.2 *Radiant Output Measurement.* Immediately following verification that the infrared heater has reached steady state conditions, use the radiometer to measure the radiant output at each nodal point in the measuring plane. The measured value of radiant output at each node shall be recorded.

The radiometer axis shall not incline by more than 2 degrees from perpendicular to the measurement plane.

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

C5.3 *Calculation of Radiant Output Heat.* The radiant output 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.

C5.3.1 *Average Voltage of a Measuring Cell.* The average appliance voltage of a cell (U_{if}) is given by Equation C1.

$$U_{if} = \frac{U_{i-1,j-1}+U_{i-1,j}+U_{i,j-1}+U_{ij}}{4} \qquad \text{C1}$$

Where:
U_{if} = Average voltage V
U_{ij} = Voltage at a node, V
$i \in (1,2,\ldots.m)$
$j \in (1,2,\ldots.k)$

C5.3.2 *Average Irradiance of the Measuring Cell.* The average irradiance of a measuring cell is given by Equation C2.

$$E_{if} = U_{if} \cdot a + b \qquad \text{C2}$$

Where:

U_{if} = Average voltage, V
a = Calibration factor gradient of the line
b = Calibration factor signal offset

C5.3.3 *Radiant Output.* The radiant output $Q_{(R)M}$ is given by Equation C3.

$$Q_{(R)M} = E_{if} \sum_{(i=1,f=1)}^{(i=n,f=k)} F_{if} \qquad \text{C3}$$

Where:
E_{if} = Average irradiance of a measuring cell, W/ m^2
F_{if} = Area of measuring cell, m^2
$f \in (1,2, \dots . k)$
$i \in (1,2, \dots . m)$
$Q_{(R)M}$ = Radiant Output, W

C5.4 *Calculation of Heat Input.* The heat input Q_m to the appliance is given by Equation C4.

$$Q_m = \frac{V_o(H_s)}{1000} \qquad \text{C4}$$

$$V_o = V\left[\frac{288.75}{273.15+t_g} \cdot \frac{p_{a+p}}{1013.25}\right] \qquad \text{C5}$$

Where:
H_s = Gross calorific value of the test gas, kWh/m^3
p_a = Atmospheric pressure, mbar
p = Gas supply pressure, mbar
Q_m = Measured heat input, W
t_g = Gas temperature at measuring point, °C
V = Gas volume input at test conditions, m^3/h
V_0 = Gas volume rate under reference conditions (15°C, 1013.25 mbar, dry gas), m^3/h

C5.5 *Correction of Measured Output for Absorption by Air.* Only the absorption of water vapor (H_2O) and carbon dioxide (CO_2) in air are considered for corrections to measured output.

C5.5.1 *Thickness of Radiation Gas Layer (D).* The thickness of the radiation gas layer is given by Equation C6.

$$D = 1.57 \cdot R - \frac{0.57R}{1+0.183\left(L/R\right)} \qquad \text{C6}$$

Where:
D = Thickness of radiation gas layer, m
L = Length of the radiating surface of the heater, m
R = Minimum distance between the radiometer and the radiation reference plane, m

C5.5.2 *Absorption of Radiation by Water Vapor.* The absorption factor (A_{H_2O}) is calculated using Equation C7.

$$A_{H_2O} = 1 - e^{\left(-k_{H2O(t_a)} \cdot (p_{H_2O} \cdot D)^n\right)} \qquad \text{C7}$$

Where:
A_{H_2O} = Absorption factor of water vapor
$k_{H_2O(t_a)}$ = Coefficient of the water vapor emission factor at temperature t_a, kPa^{-1} m^{-1}

p_{H_2O} = Partial pressure of water vapor in ambient air, kPa
D = Thickness of Radiation Gas Layer, m
t_a= Average ambient air temperature, ºC

$$n = 0.7032 \cdot \left(p_{H_2O} \cdot D\right)^{-0.0972} \qquad \text{C8}$$

C5.5.2.1 *Partial Pressure of Water Vapor in Ambient Air.* Partial pressure of water vapor in ambient air is calculated using Equation C9.

$$p_{H_2O} = 0.1 \cdot \frac{r_h}{100} \cdot 6.1078 \cdot (e^{17.08 * \frac{t_a}{243.175 + t_a}}) \qquad \text{C9}$$

Where:
r_h = Relative humidity, %
t_a = Average ambient air temperature, ºC

C5.5.2.2 *Coefficient of the Water Vapor Emission Factor at Ambient Temperature.* The Coefficient of the water vapor emission factor at ambient temperature is calculated using Equation C10.

$$K_{H_2O(t_a)} = a_{H_2O} + b_{H_2O} \cdot \frac{t_a}{1000} \qquad \text{C10}$$

Where:

$$a_{H_2O} = 0.062 \cdot \left(p_{H_2O} \cdot D\right)^{0.0283} \qquad \text{C11}$$

$$b_{H_2O} = 0.0038 \cdot ln\left(p_{H_2O} \cdot D\right) - 0.0463 \qquad \text{C12}$$

C5.5.3 *Absorption of Radiation by Carbon Dioxide.* The absorption factor of carbon dioxide (A_{CO_2}) is given by Equation C13.

$$A_{CO_2} = 1 - e^{\left[-k_{CO_2(t_a)} \cdot (p_{CO_2} \cdot D)^n\right]} \qquad \text{C13}$$

Where:
p_{CO_2} = partial pressure of carbon dioxide in ambient air
D = average thickness of the radiating gas layer, m

C5.5.3.1 *Partial Pressure of Carbon Dioxide in Ambient Air.* The partial pressure of carbon dioxide p_{CO_2} is approximately equal to 0.03 kPa corresponding to a content of 300 ppm in CO_2 in air.

C5.5.3.2 *Coefficient of the Carbon Dioxide Emission Factor at Ambient Temperature.* The Coefficient of the carbon dioxide emission factor at ambient temperature is calculated using Equation C14.

$$k_{CO_2(t_a)} = a_{CO_2} + b_{CO_2} \cdot \frac{t_a}{1000} \qquad \text{C14}$$

Where:
a_{CO_2}= 0.0532
b_{CO_2} = 0.00168
n = 0.527

C5.5.4 *Total Radiation Absorption Factor.* The total radiation absorption factor A_{ToT} for water vapor and carbon dioxide for a radiant output $Q_{(R)M}$ is given by Equation C15.

$$A_{TOT} = A_{co_2} + \beta \cdot A_{H_2O} \cdot (1 - A_{co_2}) \qquad \text{C15}$$

Where:
A_{TOT} = Total radiation absorption factor
A_{co_2} = Absorption factor of carbon dioxide, Equation C13
A_{H_2O} = Absorption factor of water vapor, Equation C7

$$\beta = 1 + \frac{p_{H_2O}}{100} \cdot (0.76 - 0.0328 \cdot \sqrt{p_{H_2O} \cdot D}) \quad \text{C16}$$

This equation is valid for p_{H_2O} values between 0 kPa to 20 kPa and (p_{H_2O}·D) values between 0 kPa-m and 1 kPA-m. The partial pressure of water vapor cannot exceed this range if the test is conducted in accordance with the standard test conditions.

C5.6 *Calculation of Corrected Radiant Output.* The radiant output corrected for absorption by water vapor and carbon dioxide is calculated using Equation C17.

$$Q_{(R)C} = \frac{Q_{(R)M}}{1 - A_{TOT}} \quad \text{C17}$$

Where:
A_{TOT} = Total radiation absorption factor
$Q_{(R)C}$ = Radiant output corrected for absorption by water vapor and carbon dioxide, W
$Q_{(R)M}$ = Radiant output, W

C5.7 *Calculation of Gross Radiant Coefficient.* The gross radiant coefficient of the appliance is given by Equation C18.

$$R_f = \frac{Q_{(R)C}}{Q_m} \quad \text{C18}$$

Where:
Q_m = Measured heat input, W
$Q_{(R)C}$ = Radiant output corrected for absorption by water vapor and carbon dioxide, W

APPENDIX D. RADIOMETER SOURCE - INFORMATIVE

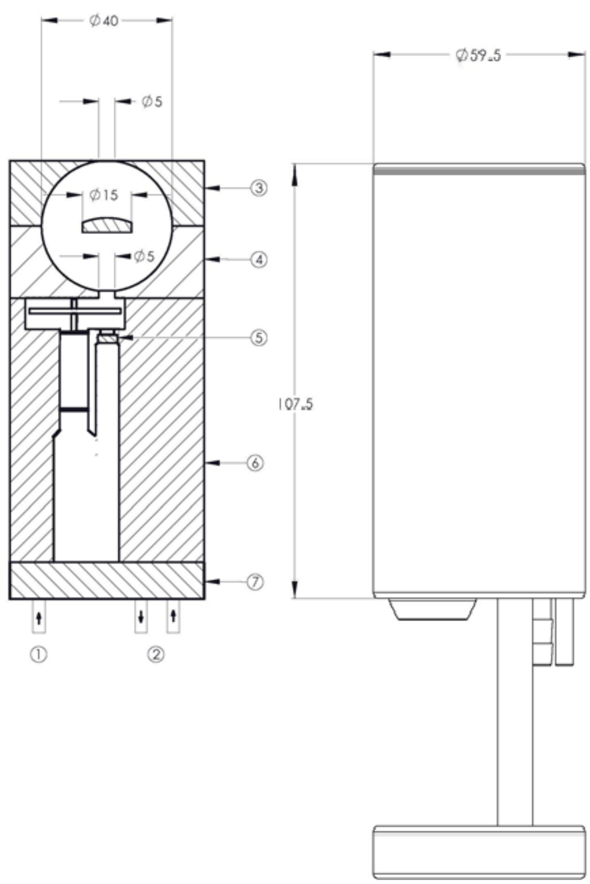
D1 *Radiometer Equipment Source*. A manufacturer of a suitable radiometer known to the Committee is DVGW-Forschungsstelle, am Engler-Bunte-Institut, des Karlsruher Instituts für Technologie (KIT), Prueflaboratorium Gas, Engler-Bunte-Ring 7, D-76131 Karlsruhe (Germany) (www.dvgw-ebi.de). An equivalent designed in conjunction with the method of test (Method B) EN 416-2 and EN 419-2 may be used. AHRI Standard 1330 is based on EN 416-2 and EN 419-2 and uses the same test equipment. The details of the design are proprietary information of DVGW.

APPENDIX E. RADIOMETER DESIGN FEATURES - INFORMATIVE

E1 *Principles of Radiometer Design Features.* The radiation enters the radiometer through the upper orifice in Plate I, Figure E1, 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 center 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 0V and 10V.

E2 *Nitrogen Purging of the Radiometer.* To protect the internal parts of the probe and the surfaces of the integrating sphere against the intrusion of dust or gas and any condensation, the probe is continuously purged with dry nitrogen. The pipes for supplying and removal of nitrogen must be protected from the influence of radiation.

E3 *Radiometer Technical Design.* Figure E1 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 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.



Key	Description
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 E1. Radiometer Design

E4 *Chopper Frequency.* Adjusting the frequency of the chopper wheel is necessary for correct operation of the amplifier given the frequency of the electrical power supply.

E5 *Pyro-electric Detector.* It is recommended to use a pyro-electric detector (e.g $LiTaO_3$) 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). All electrical wiring should be protected from external electromagnetic compatibility influences.

E6 C*alibration of Radiometer.* The calibration of the radiometer should include the complete apparatus of the radiometer, chopper controller, connecting cables, nitrogen supply, radiometer cooling system, and amplifier electronics. The calibration of the radiometer must be carried out over the range of possible radiant intensities of tube and luminous heaters. This is reached by calibration at following suggested temperatures of the black body emitter. Temperatures of the black body emitter: 80, 150, 300, 550°C. The frequency and voltage should be recorded for the power supply and the chopper. During calibration, the radiometer should be operated in the same conditions and settings as those used for measuring radiation, utilizing the same wiring, amplifier and other components. To improve accuracy when a low surface temperature radiant heater is being tested, it is recommended to determine a calibration factor at lower black body temperatures in the representative range of the heater temperatures.

E6.1.1 *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 (ε ≅ 1) with a temperature of 600°C gives the same irradiance as a high intensity radiant heater (ε <1) with a temperature of 900°C.

E6.1.1.1 *Irradiance*. The irradiance E (kW/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 E1.

$$E = \frac{\sigma\,(T^4 - 293^4)}{1000} \qquad \text{E1}$$

Where:
σ = 5.67×10^{-8}, (W/m^2K^4)
T = Temperature, K

The calibration should be carried out over the whole range of irradiances of the infrared heaters. This is achieved by calibration at several temperatures of the black body. For every temperature, the measurements should be carried out at least three times and the average of the values calculated. Thermal equilibrium should be achieved at each of the measurement temperatures prior to taking the measurements. The Calibration Factor for the whole range of irradiances is determined from the average of the measured voltages by using graphical methods and statistical means (Table E1). The irradiance is plotted against the voltage output of the radiometer (see Figure E2). The calibration factor is given by the best fitted, straight line, through the point of origin (Equation E2).

According to the graph and using Equation E2:

The calibration should be carried out for irradiances up to at least 20 kW/m^2.

Table E1. Example of Measured Output During Calibration

Black Body Temperature, °C	Average Output Signal, V	Irradiance, kW/m²
100	0.299	0.680
150	0.573	1.398
202	0.990	2.469
250	1.557	3.825
300	2.487	5.695
352	3.605	8.235
402	4.776	11.354
452	6.284	15.249
500	8.037	19.828

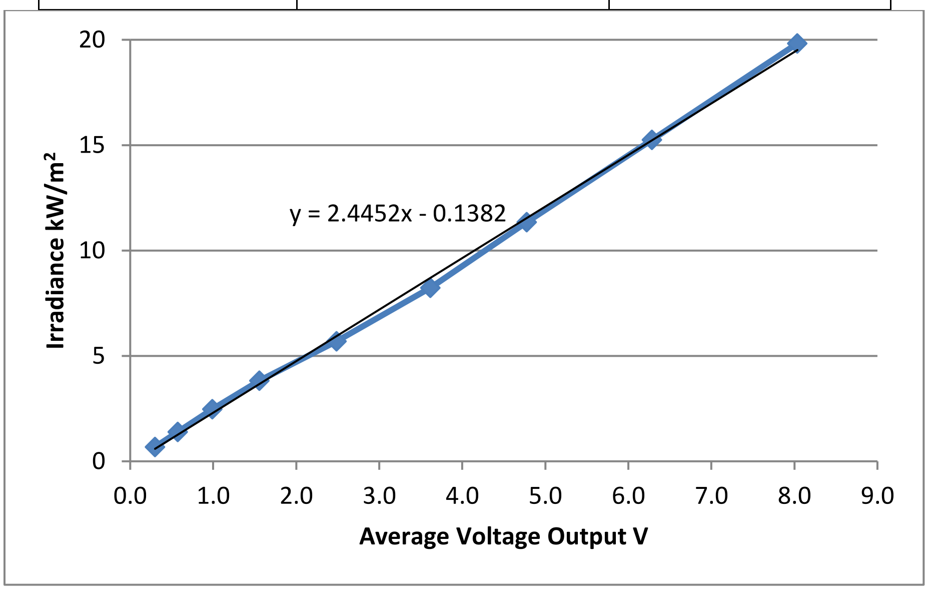


Figure E2. Determination of the Calibration Factor

E6.2 *Determination of the Calibration Factor of the Radiometer.* The calibration factor of the radiometer in the known temperature range of the black body emitter becomes a straight line by Equation E2.

$$y = ax + b \qquad \text{E2}$$

Where:
y = Radiant intensity, kW/m^2
x = Measured voltage, V
a = Gradient of the straight line
b = Signal offset

APPENDIX F. RADIANT HEAT OUTPUT DATA - INFORMATIVE

F1 *General Information to be Recorded.*

F1.1 *Test and Appliance Data.*

Test Laboratory:____________________

Manufacturer:____________ Technician:____________

Heater Type: ____________ Test date:____________

Supplier: ____________ Tube configuration:____________

Model:____________ Tube diameter, m:____________

Heater length, m:____________ Orifice size, m:____________

Heater width, m:____________ Flue length (if applicable):____________

Nominal heat input, kW:____________ Flue diameter (if applicable):____________

Air plate configuration:____________ Reflector profile:____________

Fresh air intake length (if applicable):____________ Reflector insulation (if applicable):____________

Fresh air intake diameter (if applicable):____________ Heater angle (if not horizontal):____________

Test gas gross calorific value at 15ºC and 1013.25 mbar, kWh/m^3:____________

F1.2 *Radiometer Technical Data.*

Radiometer name/number:____________________

Sensor type:____________________

Cooling system:____________________

Calibration certificate:____________________

Calibration Factor, a·x+b:____________________

Nitrogen gas flow rate, L/h:____________

Sensor temperature, ºC: ____________ Sensor temperature calibration, ºC:____________

Chopper frequency, Hz:____________

Note: Measuring equipment shall be protected from direct radiant heat.

F1.3 *Measuring Plane Technical Data.*

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

Number of measuring points (perpendicular with longitudinal axis): ____________

Measurement from start of heater to first column of nodes, mm: ____________

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 outliner lines smaller than 1% of the maximum value (Yes/No):____________

F2 *Measurement Results.*

F2.1 *Test Ambient Conditions.*

Parameter	Test Number				
	1	2	3	4	5
Air Temperature at start, ºC					
Air Temperature at end, ºC					
Ambient humidity at start, %					
Ambient humidity at end, %					
Atmospheric pressure (p_a) at start, mbar					
Atmospheric pressure (p_a) at start, mbar					

F2.2 *Gas/Heat Input Data.*

Parameter	Test Number				
	1	2	3	4	5
Gas Category					
Gross calorific value H_s, kWh/m^3					
Gas flow at ambient conditions, m^3/h					
Gas temperature, t_g, ºC					
Gas flow at 15°C and 1013 mbar, m^3/h					
Heat input Q, kW					
Supply gas pressure, mbar					
Manifold gas pressure, mbar					

F2.3 *Absorption of Water Vapor and CO_2 Data.*

Parameter	Test Number				
	1	2	3	4	5
Thickness of radiating gas layer, D (m)					
Partial Pressure of water vapor in ambient air pressure, kPa					
Coefficient in equation for emission factor of water vapor $K_{H_2O(ta)}$, k$PA^{-1}m^{-1}$					
Absorption factor of water vapor, A_{H_2O}					
Absorption factor of carbon dioxide, A_{CO_2}					
Radiant correction factor for water vapor and CO_2 air, A_{ToT}					

F2.4 *Irradiation Measurement Data.*

Parameter	Test Number				
	1	2	3	4	5
Sensor temperature, t_s, at start, ºC					
Sensor temperature, t_s, at end, ºC					
Measured radiant output, W					
Measured radiant output after correction for absorption, $Q_{(R)M}$, W					
Gross radiant coefficient, R_f					
Infrared Factor					

Name:
Signature: