BS EN 62798:2014

Incorporating corrigendum November 2014

BSI Standards Publication

Industrial electroheating equipment — Test methods for infrared emitters

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 62798:2014. It is identical to IEC 62798:2014, incorporating corrigendum November 2014.

The UK participation in its preparation was entrusted to Technical Committee PEL/27, Electroheating.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2014

ISBN 978 0 580 88995 0

ICS 25.180.10

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2014.

Amendments/corrigenda issued since publication

Date	Text affected
31 December 2014	Implementation of IEC corrigendum November 2014: formula 6 added to subclause 7.5.3

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62798

October 2014

ICS 25.180.10

Incorporating corrigendum November 2014

English Version

Industrial electroheating equipment - Test methods for infrared emitters (IEC 62798:2014)

Chauffage électrique industriel - Méthodes d'essais des émetteurs de rayonnement infrarouge (CEI 62798:2014)

Industrielle Elektrowärmeeinrichtungen - Prüfverfahren für Infrarotstrahler (IEC 62798:2014)

This European Standard was approved by CENELEC on 2014-09-29. CENELEC 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 CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 62798:2014 E

Foreword

The text of document 27/938/CDV, future edition 1 of IEC 62798, prepared by IEC/TC 27 "Industrial electroheating and electromagnetic processing" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62798:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-06-29
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-09-29

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62798:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60519-1:2010	NOTE	Harmonized as EN 60519-1:2011 (not modified).
IEC 62471:2006	NOTE	Harmonized as EN 62471:2008 (modified).
IEC 60079-0	NOTE	Harmonized as EN 60079-0.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
		Methods of test for dense shaped refractory products - Part 11: Determination of resistance to thermal shock	EN 993-11	
IEC 60061-1	-	Lamp caps and holders together with gauges for the control of interchangeability and safety - Part 1: Lamp caps	EN 60061-1	-
IEC 60061-2	-	Lamp caps and holders together with gauges for the control of interchangeability and safety - Part 2: Lampholders	EN 60061-2	-
IEC 60061-3	-	Lamp caps and holders together with gauges for the control of interchangeability and safety - Part 3: Gauges	EN 60061-3	-
IEC 60068-2-6	-	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	-
IEC 60068-2-7	-	Basic environmental testing procedures - Part 2-7: Tests - Test Ga and guidance: Acceleration, steady state	EN 60068-2-7	-
IEC 60432-1 (mod)	1999	Incandescent lamps - Safety specifications - Part 1: Tungsten filament lamps for domestic and similar general lighting purposes	EN 60432-1	2000
+A1	2005		+A1	2005
+A2	2011		+A2	2012
IEC 60519-12	-	Safety in electroheating installations - Part 12: Particular requirements for infrared electroheating installations	EN 60519-12	-
IEC 60682	1980	Standard method of measuring the pinch temperature of quartz-tungstenhalogen lamps	EN 60682	1993
+A1	1987			
+A2	1997		+A2	1997
IEC 62693	2013	Industrial electroheating installations - Test methods for infrared electroheating installations	EN 62693	2013

CONTENTS

INTRODUCTION

This standard on particular test methods for infrared electroheating emitters is one of TC 27 standards that describe test methods for various types of electroheating installations.

This standard is solely concerned with tests for infrared emitters. Tests that focus on the performance of infrared equipment or installations are covered by IEC 62693, *Industrial electroheating installations – Test methods for infrared electroheating installations*. The rationale for this separation is that infrared installations are usually manufactured by other companies than infrared emitters. Still, infrared emitters are a very important and distinct part of infrared installations and a set of tests that allow for proper characterisation, comparison of different infrared emitters is valuable to manufacturers of infrared installations.

The major guiding principle for this standard is to determine

– simple tests that define the basic characteristics of all infrared emitters and can be performed with the usual test and measuring equipment available to different kinds of companies, large or small;
– more complex tests that provide valuable extra information, but need a well-equipped laboratory.

INDUSTRIAL ELECTROHEATING EQUIPMENT –

Test methods for infrared emitters

1 Scope and object

This International Standard specifies test procedures, conditions and methods according to which the main parameters and the main operational characteristics of industrial infrared emitters are established.

A limitation of the scope of this standard is that the infrared emitters have a maximum spectral emission at longer wavelengths than 780 nm in air or vacuum, and are emitting wideband continuous spectra such as by thermal radiation or high pressure arcs.

IEC 60519-1:2010 [1] [1] defines infrared as optical radiation within the frequency range between about 400 THz and 300 GHz. This corresponds to the wavelength range between 780 nm and 1 mm in vacuum. Industrial infrared heating usually uses infrared sources with rated temperatures between 500 °C and 3 000 °C; the emitted radiation from these sources dominates in the wavelength range between 780 nm and 10 μm.

Industrial infrared emitters under the scope of this standard typically use the Joule effect for the conversion of electric energy in one or several sources into infrared radiation, which is emitted from one or several elements. Such infrared emitters are especially

– thermal infrared emitters in the form of tubular, plate-like or otherwise shaped ceramics with a resistive element inside;
– infrared quartz glass tube or halogen lamp emitters with a hot filament as a source;
– non-insulated elements made from molybdenum-disilicide, silicon-carbide, iron-chromium-aluminium alloys or comparable materials;
– wide-spectrum arc lamps.

This standard is not applicable to

– infrared emitters which are lasers or light-emitting diodes (LEDs);
– infrared emitters for use by the general public;
– infrared emitters for laboratory use.

Most of the tests described, especially the destructive tests, are for type testing.

The tests specified in this standard are intended to be used for evaluating or comparing the performance of emitters belonging to the same category.

Tests related to performance of industrial infrared electroheating installations are specified in IEC 62693:2013.

Most tests specified in this standard are applicable to wide-spectrum arc lamps, but not all.

---

1 Numbers in square brackets refer to the Bibliography.

2 Normative references

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

IEC 60061-1, *Lamp caps and holders together with gauges for the control of interchangeability and safety – Part 1: Lamp caps*

IEC 60061-2, *Lamp caps and holders together with gauges for the control of interchangeability and safety – Part 2: Lampholders*

IEC 60061-3, *Lamp caps and holders together with gauges for the control of interchangeability and safety – Part 3: Gauges*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-7, *Basic environmental testing procedures – Part 2-7: Tests – Test Ga and guidance: Acceleration, steady state*

IEC 60432-1:1999, *Incandescent lamps – Safety specifications – Part 1: Tungsten filament lamps for domestic and similar general lighting purposes*
IEC 60432-1:1999/AMD1:2005
IEC 60432-1:1999/AMD2:2011

IEC 60519-12, *Safety in electroheating installations – Part 12: Particular requirements for infrared electroheating installations*

IEC 60682:1980, *Standard method of measuring the pinch temperature of quartz-tungsten-halogen lamps*
IEC 60682:1980/AMD1:1987
IEC 60682:1980/AMD2:1997

IEC 62693:2013, *Industrial electroheating installations – Test methods for infrared electroheating installations*

EN 993-11, *Methods of test for dense shaped refractory products – Part 11: Determination of resistance to thermal shock*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60519-12, IEC 62693 as well as the following apply.

NOTE General definitions are given in the International Electrotechnical Vocabulary, IEC 60050 [2]. Terms relating to industrial electroheating are defined in IEC 60050-841.

3.1 General

3.1.1
infrared radiation
optical radiation for which the wavelengths are longer than those for visible radiation

Note 1 to entry: The infrared radiation range between 780 nm and 1 mm is commonly subdivided into:

IR-A 780 nm to 1 400 nm, or for a grey emitter 3 450 °C to 1 800 °C surface temperature;

IR-B 1 400 nm to 3 000 nm, or for a grey emitter 1 800 °C to 690 °C surface temperature;

IR-C 3 000 nm to 1 mm, or for a grey emitter less than 690 °C surface temperature.

The temperature corresponds to a spectrum where maximum intensity is at the wavelength of the limit.

These ranges comply with IEC 62471:2006 [3].

Note 2 to entry: In IEC 60050-841:2004 the following terms are defined:

841-24-04 – shortwave infrared radiation or near infrared radiation (780 nm to 2 µm);

841-24-03 – mediumwave infrared radiation or medium infrared radiation (2 µm to 4 µm);

841-24-02 – longwave infrared radiation or far infrared radiation (4 µm to 1 mm).

These terms are not used in this standard.

[SOURCE: IEC 60519-12:2013, 3.101]

3.1.2
emitter category
group of emitters using the same principle for applying thermal energy to the workload

3.1.3
inrush current
short term high lamp current occurring during the transient period from the moment of applying voltage to a cold emitter to steady state

3.1.4
average electrical lifetime
net operating time of infrared emitters at rated voltage under intended conditions when 50 % of all emitters are still operating

3.2 Radiation

3.2.1
radiant power
radiant flux
power emitted, transmitted or received in the form of radiation

3.2.2
irradiance
irradiation
quotient of the radiant power incident on a surface element containing the point, by the area of that element

3.2.3
radiance

quantity L defined by the formula $L = \dfrac{d\Phi}{dA \cdot \cos\theta \cdot d\Omega}$

where

$d\Phi$ is the radiant power or flux transmitted by an elementary beam passing through the given point and propagating in the solid angle containing the given direction;

$d\Omega$ is the solid angle;

dA is the area of a section of that beam containing the given point;

$\cos\theta$ is the angle between the normal to that section and the direction of the beam.

3.2.4
radiant exitance, <of a body>
quotient of the radiant flux emitted by a body into the hemispherical space (2π sr) by the surface unit area of that body

Note 1 to entry: The body can be an infrared emitter or a source of an infrared emitter.

3.2.5
spectral distribution
spectrum
quotient of a radiant quantity $dX(\lambda)$ contained in an elementary range $d\lambda$ of wavelength at the wavelength λ by that range

Note 1 to entry: The term spectral distribution is preferred when dealing with the function $X\lambda(\lambda)$ over a wide range of wavelengths, not at a particular wavelength.

3.2.6
spectral radiance
ratio of the radiant power $d\Phi(\lambda)$ passing through a point and propagating within the solid angle $d\Omega$ in the given direction, to the product of the wavelength interval $d\lambda$ and the area of a section of that beam on a plane perpendicular to this direction ($\cos\theta \cdot dA$) containing the given point and to the solid angle $d\Omega$

3.2.7
spectral radiant exitance
quotient of the radiant flux emitted by a body into the hemispherical space (2π sr) by the surface unit area of that body and by the unit wavelength interval

3.2.8
radial irradiation distribution
irradiation caused by any emitter of axial symmetry on a circumference around the axis of symmetry of the emitter on a plane perpendicular to that axis and centred at mid-length of the emitter

Note 1 to entry: Axial symmetry does not imply round.

3.2.9
rated total radiant power
radiant power emitted by the emitter at rated voltage

4 Classification of infrared emitters

The most common industrial infrared emitters under the scope of this standard emit broadband thermal spectra. Annex A provides basic definitions and concepts of thermal infrared radiation. Thermal emitters usually have a clear correlation between the maximum of the spectral radiant power and the temperature of the source of the emitter, called Wien’s law; in this case the rated temperature indicates the spectrum of the emitter. Arc lamps generate a non-thermal spectrum.

The most relevant design element of infrared emitters influencing the spatial irradiation pattern is the size and dimension of the surface of the source emitting the radiation. As industrial infrared emitters are usually used in close vicinity of the workload, there are

– very small sources which act like point sources – for example small light bulbs or arc lamps with a very short arc; infrared laser and LED are point sources as well, but are outside the scope of this standard;
– near ideal line sources – for example halogen emitter, tungsten coil emitter, arc or flash lamps; their source may be bent;
– tubular or line sources with a large diameter – for example ceramic tube emitters, heating rods made from materials like graphite or silicon carbide;
– planar or two-dimensional sources – for example ceramic tile type emitters.

Radiation sources can be divided into point like sources and extended sources depending on the size of the source and observation distance. If the distance between the radiation source of the emitter and the observation point is greater than 10 to 50 times the maximum dimension of the radiation source, this source can be approximated as a point source. In most industrial installations the infrared emitters are in close vicinity to the workload and are thus extended sources. The approximate value of 10 to 50 depends on the problem and the intended accuracy of a measurement.

NOTE 1 When the observing distance is greater than 10 times the maximum dimension of the radiation source, the resulting error for calculating the irradiance is less than 1 %.

Commonly available industrial infrared emitters classified according to their spectral emission and rated temperatures are listed in Table 1.

NOTE 2 In industry a different classification than the one used in this standard and given in 3.1.1 is also known, it is provided for information in Annex B.

Table 1 – Classification of infrared emitters by spectral emission

Spectral band where maximum of emission occurs	Rated temperature of thermal emitter	Category	Comments
IR-A 780 nm to 1 400 nm	1 800 °C to 3 450 °C	– halogen emitter – tungsten quartz tube emitter – high power laser diodes[1] – light emitting diode[1] – arc lamp[1]	Other names for this spectral range used in industry are: near infrared, NIR, short-wave[2].
IR-B 1 400 nm to 3 000 nm	690 °C to 1 800 °C	– halogen emitter – tungsten quartz tube emitter – ceramic emitter – heating wire made from nickel-chromium alloys – nichrome – heating wire made from alloys of nickel-chromium, or iron-chromium-aluminium – quartz tube emitter with heating wire coil (Cr, Al, Fe) – quartz tube emitter with carbon filament – quartz tube emitter with tungsten coil – silicon carbide heating rod – graphite heating rod – molybdenum disilicide heating element – high temperature metal tube element – high temperature ceramic element	Other name for this spectral range used in industry is "medium-wave"[2].
IR-C 3 000 nm to 1 mm	< 690 °C	– metal tube element – ceramic emitter element	Not in the scope of this standard, if convection dominates.

[1] included for reference only; rated temperature is not applicable

[2] short wave and medium wave can denote differing spectral ranges, see Annex B

5 Type of tests and general conditions of their performance

5.1 General – list of tests

Table 2 summarises the tests covered by this standard and their applicability to different categories of infrared emitters. It also includes references to other standards with applicable tests. Additional tests may be covered by commissioning and operation manuals issued by the manufacturer or may be agreed on between the manufacturer and user.

Table 2 – List of tests, their applicability to different classes of infrared emitters and the number of emitters needed for the tests

Test	Subclause	Emitter category				Manufacturing[1]	
		Open heating element	Ceramic heating element	Infrared quartz	Halogen quartz	Standard, mass produced	Made to order
emitter geometry	-	test is defined between the manufacturer and user					
interchangeability of cap and holder, standard	7.2.1	not applicable		If cap and holder combinations from Parts 1, 2 and 3 of the IEC 60061 series are used, IEC 60061-3 is applicable.			
interchangeability of cap and holder, other	7.2.2	as agreed on between the manufacturer and user					
cap twist-off test	7.2.3	not applicable		IEC 60432-1 is applicable for caps covered by that standard			
rated power	7.3.1	applicable				1/100	1/100 or 1/batch
power variation with voltage	7.3.2					1/type	1/type
inrush current	7.3.3	usually not necessary		usually applicable[1]	applicable[2]		
emitter resistivity as estimate for rated power	7.3.4	may be applicable			not applicable		
rated temperature	7.4.1	applicable				IEC 60432-1 applies	1/batch
variation of source temperature with voltage	7.4.2					1/type after change in production	1/type
source temperature rise time	7.4.3						
cooling time	7.4.4, 7.4.5, 7.4.6	source cooling = surface cooling in 7.4.5			source cooling in 7.4.4 surface cooling time in 7.4.6		
temperature homogeneity	7.4.8	applicable					
surface temperature distribution	7.4.9						
distribution temperature	7.4.10						
thermal ruggedness	7.4.11	applicable		non applicable	application dependent		10/type

Table 2 *(continued)*

Test	Subclause	Emitter category				Manufacturing	
		Open heating element	Ceramic heating element	Infrared quartz	Halogen quartz	Standard, mass produced	Made to order
pinching temperature	7.4.12	not applicable		IEC 60682		1/type, after change in production	1/type
radial irradiation distribution of tubular emitters	7.5.2	applicable for emitters with line or tubular source					
reflectivity of tubular emitter	7.5.3						
irradiation field on a surface	7.5.4	applicable					
angular irradiation field	7.5.5						
emitted spectrum	7.5.6, Annex C						
rated total radiant power	7.5.7						
irradiation reaction time	7.5.8						
acceleration resistivity	7.6.1						
vibration resistivity	7.6.2						
lifetime measurement	7.7.3	refer to 7.7.1				IEC 60432-1:1999, Annex D	not applicable
induced lamp death	7.7.4 7.7.5	not applicable, but may be agreed on between the manufacturer and user, refer to 7.7.1				IEC 60432-1:1999, Annex D	not applicable
lifetime statement	7.7.6	applicable, refer to 7.7.1				not applicable	not applicable

[1] Definitions used are:

- batch is a production batch or lot of a single product;
- type is an identifiable type differentiated by at least one specific unique characteristic from other emitters manufactured;
- changes in production are those changes that can affect the emitters manufactured and can affect the measurement results.

[2] Applicable to filaments made from materials that show a noted increase of specific resistivity with temperature, like tungsten, molybdenum, osmium, platinum.

5.2 Test conditions

5.2.1 Operating conditions during tests

Operating conditions during the tests shall be in the range of normal operating conditions of the emitter tested and thus reflect the manufacturer's intended use of the product while excluding extreme usage patterns, deliberate misuse or unauthorized modifications. Extreme usage pattern may be agreed on between the manufacturer and user.

All environmental conditions that affect measurement results shall be monitored during the tests and be part of the measurement report. This includes

a) environmental temperature including hot surfaces in the vicinity;
b) temperature of the air used for cooling;
c) relative and absolute humidity of the air at temperatures when condensation is expected to occur, i.e. below 100 °C if applicable;
d) vibration or infrasound.

All tests shall be performed with the emitter radiating into free space, or only onto sufficiently cooled and radiation absorbing surfaces at less than 50 °C in the vicinity to avoid any heating of the emitter through the vicinity.

The emitter shall be positioned so that free convection is not hindered. Free convection is not hindered if the distance to the next object in all directions including below the emitter is at least 10 times the diameter of the emitter tube or 10 times the largest dimension of a planar emitter.

5.2.2 Standard environment for tests

All tests shall be performed

a) under standardised environmental conditions, at ambient temperature in the range between 5 °C and 40 °C and air relative humidity of less than 95 %,
b) at the altitude above sea level less than 1 000 m,
c) with no forced convection of the air applied unless otherwise stated.

The ambient temperature is considered as an average value. All quantities dependent on the ambient temperature shall refer to the ambient temperature of 20 °C, the so-called reference ambient temperature.

5.2.3 Non-standard environment for tests

All tests may be performed under conditions deviating from the standard environment as defined in 5.2.2 if the infrared emitters are intended to be used under these conditions. Examples are

– at vacuum pressure inside a vacuum chamber with cold walls – i.e. less than 70 °C;
– at elevated temperature of the surrounding air;
– with forced convection in an air stream of defined velocity or mass flow rate.

The manufacturer and user may decide to perform the tests under the available environmental conditions expected inside the equipment.

5.2.4 Supply voltage

The supply voltage limits shall not exceed those defined by the manufacturer for the intended purpose.

The supply voltage applied to the emitter shall be monitored during the tests.

All measurements of specific electrical values as defined in Clause 6 shall include the measured data of the supply voltage applied to the emitter during measurement.

5.3 Stationary condition

Emitters usually need time to reach a stationary condition after changes in environmental conditions or applied voltage. It is reached when current, power and temperature of the emitter no longer change with time.

Typical periods are 2 min to 5 min for quartz tube emitters and 10 min to 15 min for ceramic emitters.

5.4 Number of emitters for tests

The emitters used for tests shall be taken at random from a production lot. Broken emitters shall be replaced from the same production lot. Table 2 defines the minimum amount of emitters necessary for the tests given in this standard.

6 Measurements

6.1 General

More than a single measurement is recommended for the tests defined in this standard. A data logger or multi-channel electronic data acquisition system shall be used for time resolved measurements. Such a device automatically measures and stores the necessary data in a computer readable format.

6.2 Time resolution

The necessary time resolution of the measuring equipment and the data saving rate of the storage device depends on the emitter and the specific tests to be undertaken. The measurement and storage frequency shall be so high that all relevant signal variations are recorded.

6.3 Measurement of electric data

6.3.1 All equipment for voltage measurement shall be of class 2.0 or better. The measuring equipment for a.c. shall be able to show true RMS independent of the waveform.

6.3.2 All equipment for current measurement shall be of class 2.0 or better. The current measuring equipment for a.c. shall be able to measure true RMS independent of the waveform.

6.3.3 All equipment for energy consumption measurement shall be of class 2.0 or better. The energy consumption measuring equipment for a.c. shall be able to measure true RMS independent of the waveform.

6.3.4 Equipment for the measurement of transient effects like inrush current, real values of voltage, current or power shall not average or provide RMS; in deviation from the requirements in 6.3.1 to 6.3.3. It shall have a sufficient time resolution as defined in 6.2.

6.3.5 Measurements of all voltages applied to the emitter shall be performed at the conductors connected to the emitter or at the power outlet of the switchgear connected to the emitter.

6.3.6 Measurements of all currents flowing through the emitter shall be performed at a conductor connected to the emitter or at the power outlet of the switchgear connected to the emitters.

6.3.7 Measurements of power use of the infrared emitter shall be performed at the power outlet of the switchgear connected to the emitters.

6.3.8 All equipment for resistance measurement shall use a four point probe and be of class 2.0 or better.

6.3.9 Any measurements that shall be performed at rated voltage shall be performed at rated voltage ± 2 %.

6.4 Temperature measurement

The kind of equipment used for temperature measurement depends on the task, the temperature range, available information on the condition of the surface being measured or the accessibility of the surface.

Contact thermocouples are simple to use and reliable. They provide reliable and exact results

– if an intimate and non-detachable contact to the surface of an object is established through the measurement and
– the object is having a sufficient high mass and good thermal conduction to the thermocouple is held throughout the measurement.

Pyrometers and infrared cameras summarised as thermographic methods may be used

a) for all surfaces at elevated temperature,
b) when the emissivity of the surface is well known,
c) when the surface is considered as lambertian – i.e. following a cosine law of angular emissivity, and
d) when the wavelength range used for detection is transmitted by any tube or window material protecting the source and being in the path of light between source and equipment.

The used value of the emissivity, the measurement wavelength and the presumed error of the emissivity shall be included in all measurement reports.

The relative measurement error for all temperature measurements in compliance with this standard shall not exceed 5 % of the temperature stated in °C of the measured value. Measurement accuracy shall be included in the measurement report.

NOTE The German VDI/VDE 3511 series [4] gives information on best practice for temperature measurement in industry.

6.5 Irradiance and radiance measurement

All measuring equipment for measurement of irradiance or radiance shall be of class 3.0 or better.

The measuring equipment shall have a flat or constant spectral response between 400 nm and 10 µm, a flat response between 200 nm and 20 µm is preferred.

The measuring equipment shall be sufficiently stabilised to avoid any drift exceeding the limits.

NOTE This can be a thermally stabilised pyro-electric detector.

6.6 Spectral measurements

6.6.1 General

The measurement of spectral functions of infrared emitters over a reasonably wide spectral range is well beyond the possibilities of most industrial companies. A meaningful spectral interval for full characterisation of an emitter can extend over the 1 % to 90 % of emitted power range (as defined in Table A.1), which corresponds to a wavelength range of about three times the wavelength at maximum emitted power. CIE 063:1984 [5] and CIE 130:1998 [6] provide methods for spectral measurements in the visible spectrum. In general, meaningful wideband spectral measurements in the infrared involve complex equipment, like some detectors and gratings in a single monochromator and the use of elaborate calibration procedures.

A measurement error of more than 20 % is to be expected unless very significant efforts are made to reduce this. Measurement data shall therefore include a description of the equipment used as well as the means used to compensate or avoid atmospheric absorption.

6.6.2 Calculation as a surrogate for measurement

Before one decides to measure any spectral data, one can consider the following: if the emissivity of the emitter is already well known from literature, Planck's law from Formula (A.1) allows the calculation of temperature dependent spectral emission with sufficient accuracy for most purposes of this standard.

6.6.3 Required spectral range

The measurement wavelength range shall cover most of the high intensity part of the spectrum, usually spanning at least from $E(\lambda,T)=0{,}01\cdot E(\lambda_{max},T)$ on the short wavelength side of the spectrum to $E(\lambda,T)=0{,}1\cdot E(\lambda_{max},T)$ on the long wavelength side. The wavelength range is derived using the generalised Wien's law data from Annex A, Table A.1. This spectral range amounts to about $3\cdot\lambda_{max}$ at rated temperature.

High spectral resolution does not matter for thermal infrared emitters due to the broad features of thermal radiation. That is unless emission is caused by a material that has very distinct spectral features in its emissivity.

Measurement of the spectral exitance of arc emitters can be done by methods developed for the visible and near infrared as defined in CIE 063:1984 [5] and CIE 130:1998 [6].

6.6.4 Measurement conditions

Any relevant measurement of infrared spectra shall take account of atmospheric absorption caused by water vapour and carbon dioxide. The fundamental bands of these molecules near 2,8 μm and 5,0 μm cause strong absorption even for short optical path lengths. Long path length leads to absorption by weaker bands and by less common molecules thus eventually covering most of the infrared spectrum. To reduce the influence of these gases the following may be applied:

– measurement in an atmosphere of nitrogen or argon,
– or comparison of the signal from the infrared emitter with that of a well-known reference light source; such a reference can be a high quality black body at comparable temperature as the source of the infrared emitter; the signal from that black body can be used to correct any atmospheric absorption.

The wavelength dependent optical transfer function of the measurement systems is either included in the measurement through a calibration using a well-known reference light source, like a halogen lamp conforming to CIE 149:2002 [7], or by using a high quality blackbody.

6.6.5 Spectral measurements

Information on spectral measurements is provided in Annex C.

7 Technical tests

7.1 General

The following test methods can be used to describe the performance of infrared emitters. The test requirements may be modified or amended as agreed upon by the manufacturer and user. If a test is modified or amended, the exact amendment or modification shall be part of any test report issued. Additional tests may be agreed between the manufacturer and user.

7.2 Tests concerning cap and holder of emitter

7.2.1 General

The following tests apply to emitters with a cap designed for a specific holder. They do not apply to emitters equipped with electric leads only.

7.2.2 Cap and holder interchangeability

If the infrared emitter has a standardized cap defined in IEC 60061-1 to be used in connection with a holder defined in IEC 60061-2, the interchangeability of cap and holder for such standard cap and holder combination shall be tested in accordance with IEC 60061-3.

The manufacturer and user may define other cap and holder combinations and shall agree in this case on specific tests or gauges to ensure interchangeability.

7.2.3 Cap twist-off test

The test according to 2.5 of IEC 60432-1:1999 and IEC 60432-1/AMD1:2005 applies.

7.3 Power consumption characteristics

7.3.1 Rated power

The rated power of the emitter shall be measured at rated voltage – see 6.5.

For emitters where the rated voltage is a standard line voltage, measurement of rated power shall include measurement at –10 % and +10 % of this rated voltage.

The electrical values at ± 10 % of rated voltage may be calculated instead, if the manufacturer has a reliable model for predicting these values based on the measurement at rated voltage. A reliable model is characterised by the ability to predict electrical values at error-margins comparable to measurements conforming to this standard.

7.3.2 Variation of power with voltage

Measurement of the dependency of electrical emitter power on voltage shall be done with the same emitters as that used for the measurement in 7.3.1.

The variation of power used by the emitter depending on the applied voltage shall be measured starting from 0 V up to 110 % of the rated voltage. The voltage increase between measurement points shall be 10 % of the rated voltage or smaller. The measurement shall be performed at stationary condition for each step.

NOTE Performing this measurement by decreasing the voltage can result in different values if stationary condition is not reached for each single measurement point.

The variation of electrical values with applied voltage may be calculated instead, if the manufacturer has a reliable model for this. A reliable model is characterised by the ability to predict electrical values at error-margins comparable to measurements conforming to this standard.

7.3.3 Inrush current

Inrush current of emitters depends on the impedance of the power supply used in an installation. This test shall assess unfavourable conditions. Therefore the power supply used shall have low impedance and shall be directly connected to a high current line supply.

The minimum time resolution shall be 1 ms as inrush current tends to peak early in the very first cycle after switch on. The inrush current is assessed by comparing the maximum measured current with a measurement of current under stationary condition.

The extent of inrush current depends critically on the exact moment of switch on during a single phase. Generally, switch on at zero voltage underestimates the effects. Switch on at peak voltage is preferred as this is the worst case.

Theoretical maximum inrush current may be calculated instead, if the manufacturer has reliable data on the variation of electric resistivity with temperature of the filament material of the emitter and the rated temperature is known – see 7.4.1.

7.3.4 Emitter resistivity as estimate for rated power

The measurement of cold state electrical resistivity as an indication of rated electric power can provide a meaningful test for infrared emitter with small or negligible variation of the electric resistivity with temperature.

NOTE This typically applies for emitter where the conversion of electric energy into heat is confined to an element made from iron-chromium-aluminium alloys.

The minimum requirements for such a test, allowing comparison or estimation of rated power, are the following:

a) For each emitter the rated power and the rated resistivity at room temperature shall be established by the manufacturer.
b) Measurement accuracy for voltage, current and power shall be class 1.
c) The measuring equipment for resistivity shall use a 4 point probe and shall be class 1.
d) Calibration intervals for all measuring equipment shall be less than 1 year.
e) The measurement of cold state resistivity of the emitter shall be performed at 20 °C ± 3 °C emitter temperature and air temperature of the testing room. The emitter shall have rested at this temperature over at least one hour without being touched or switched on, rest over 24 h is preferred.

When the comparison of results is intended, like in a quality check, a regular round robin test is mandatory. Usually all parties should use identical measuring equipment.

Annex G discusses error sources and possible application of such a test.

7.4 Emitter temperature tests

7.4.1 Rated temperature

7.4.1.1 General

The rated temperature is measured at rated voltage. It is measured under standard environmental conditions. Information on rated temperature measurements at deviating environmental conditions shall include a statement describing the conditions of measurement.

The test method for the rated temperature varies with the emitter type and with the intended accuracy; thus the employed method shall be part of the test report.

7.4.1.2 Filament emitters

In case of emitters where a filament like a tungsten coil or a carbon filament is placed inside a quartz tube or similar,

a) temperature variations over the length and width of the filament are very hard to assess,
b) the filament is dominated by surface areas at one temperature which is usually the highest temperature of the filament as well.

In this case the rated temperature is the maximum temperature measured on the emitting surface of the emitter source. The test shall be performed at stationary condition.

7.4.1.3 Other emitters

Emitters with extended sources usually show a broader variation of the temperature on the surface of the source.

In this case the rated temperature can be approximated through one of the following:

a) The average temperature measured on the surface of the source of the emitter using the method defined in 7.4.7. This test slightly underestimates the temperature defining the spectral radiance. The measurement area for the average temperature shall be the effective radiant surface of the emitter or source.
b) The maximum temperature measured on the surface of the source of the emitter. This test slightly overestimates the temperature defining the spectral radiance.
c) The calculation of the distribution temperature from the spectral radiance as defined in 7.4.10.
d) The effective temperature of the surface of the source – which usually corresponds to the radiant power being greater than 90 % of the total radiant power.

Unless the spectral emission is dominated by one area with homogenous temperature, method a) shall be used.

7.4.2 Variation of source temperature with voltage

Measurement of the dependency of source temperature on voltage shall be done with the same emitters as those used for the measurement in 7.4.1.

The variation of temperature of the emitter depending on the applied voltage shall be measured starting from 0 V up to 110 % of the rated voltage. The voltage increase between measurement points shall be 10 % of the rated voltage or smaller. The measurement shall be performed at stationary condition for each step.

NOTE Performing this measurement by decreasing the voltage can result in different values if stationary condition is not reached for each single measurement point.

The variation of source temperature with applied voltage may be calculated instead, if the manufacturer has a reliable model for this. A reliable model is characterised by the ability to predict electrical values at error-margins comparable to measurements conforming to this standard.

7.4.3 Source temperature rise time

The source temperature rise time is defined as the time needed for the radiation emitting surface to reach 90 % of rated temperature counted from the moment of applying the rated voltage to an emitter in the cold state.

The measurement shall be performed using the same emitter as that used for the measurement of rated temperature in 7.4.1.

7.4.4 Source temperature cooling time for quartz tube emitters

The source temperature cooling time for all types of infrared emitters where the source is inside an emitter tube is defined as the time needed for the radiation emitting surface of the source to cool down to 500 °C from rated temperature counting after power has been turned off.

The measurement shall be performed with the same emitter as that used for the measurement in 7.4.1. A source temperature of 500 °C is assumed the minimum temperature to create relevant infrared emission for this kind of emitter.

7.4.5 Source temperature cooling time for other emitters

The source temperature cooling time for all types of infrared emitters where the source is in direct contact to the environment is defined as the time needed for the radiation emitting surface to cool down below the following set of temperatures from rated temperature counting after power has been turned off.

These temperatures are T_1 = 450 °C, T_2 = 300 °C, T_3 = 200 °C, T_4 = 135 °C, T_5 = 100 °C, T_6 = 85 °C. The temperatures correspond to the temperatures used in the temperature classification according to IEC 60079-0 [8]. These values give the user an estimate after how much time such an emitter may come into contact with possibly flammable atmospheres.

The measurement shall be performed with the same emitter as that used for the measurement in 7.4.1.

7.4.6 Quartz tube cooling time for quartz tube emitters

The quartz tube cooling time is defined as the time needed for the hottest spot on the outer surface of the emitter to cool down from stationary condition temperature to below the following set of temperatures from the operating temperature counting after power has been turned off.

These temperatures are T_1 = 450 °C, T_2 = 300 °C, T_3 = 200 °C, T_4 = 135 °C, T_5 = 100 °C, T_6 = 85 °C. The temperatures correspond to the temperatures used in the temperature classification according to IEC 60079-0 [8]. These values give the user an estimate after how much time such an emitter may come into contact with possibly flammable atmospheres.

The measurement shall be performed with the same emitter as that used for the measurement in 7.4.1.

7.4.7 Source temperature distribution

A wide temperature distribution of the source of an emitter can indicate a variation of output power if

– in the case of quartz tube or halogen, emitter different coil segments between spacers show different maximum temperatures;

– in the case of tubular emitters, if temperature increases or decreases from one end to another;

– in case of planar sources, a variation of temperature between surface areas where resistive elements are below the surface.

It is preferred that this test is performed

– with a thermographic camera, or
– using a pyrometer.

When a thermographic camera is used, the complete source shall be measured at once, and the measurement points are all pixels of the thermal photo being part of the image of the source.

When a pyrometer is used the measurement points shall be

a) distributed homogeneous on the surface of planar sources, the number of measurement points shall be sufficient to resolve major structures but not less than 9 or
b) distributed equidistant over linear or tubular sources, the number of measurement points shall be sufficient to resolve major structures but not be less than 5.

The layout of measurement points shall be adapted to relevant structural features of an emitter.

For some emitters with complex geometry, a contact thermometer is preferred to perform this test. The measurement points shall be selected evenly, separately on the surface of heating parts and non-heating parts.

The measurement report shall indicate the measurement method, the measurement positions, average temperature, minimum, maximum and variance of the temperature.

7.4.8 Average temperature calculation from a thermal image

The average temperature is calculated using data from all pixels that are fully irradiated by the part or surface only (pixels not fully covering a hot surface show lower temperature due to lower signal).

$$\overline{T} = \left(\frac{1}{n} \sum_{i=1}^{n} T_i^4 \right)^{\frac{1}{4}} \tag{1}$$

where

n is the number of pixels of the thermal image clearly being part of the measured surface;

T_i is the temperature value of the i-th pixel of thermal image clearly being part of the measured surface.

7.4.9 Surface temperature distribution

It is preferred that this test be performed

– with a thermographic camera, or
– using a pyrometer.

When a thermographic camera is used, the complete visible surface shall be measured at once and the measurement points are all pixels of the thermal photo being part of the image of the surface of the emitter.

When a pyrometer is used the measurement points shall be

a) distributed homogeneous on the surface of planar sources, the number of measurement points shall be sufficient to resolve major structures but not less than 9 or
b) distributed equidistant over linear or tubular sources, the number of measurement points shall be sufficient to resolve major structures but not be less than 5.

The layout of measurement points shall be adapted to relevant structural features of an emitter.

For emitters with complex geometry, where part of the surface is optically not accessible or optical methods can provide limited accuracy, a contact thermometer is preferred to perform the test. The definition of measurement positions shall follow the same rule as for use of a pyrometer, i.e. the positions shall be distributed homogeneously and equidistant over the surface; in case only a part of the surface is heated, both heated and unheated parts shall be covered with measurement positions.

The measurement report shall indicate the measurement method, the measurement positions, average temperature, minimum, maximum and variance of the temperature.

7.4.10 Distribution temperature

Estimating the distribution temperature is discussed in CIE 114/4 [9] for visible light sources. The concept can be used for the description of the spectral emission of infrared emitters as well.

NOTE The procedure is valid for errors that scale with the measured irradiance.

The distribution temperature is determined from the measured or calculated emitted radiation spectrum of the emitter; the data is usually a set of spectral radiant power values at specific wavelengths $M(\lambda_i)$ – refer to 6.6 and Annex C for measurement or Annex A for calculation. When the spectral radiant power distribution of the emitter is comparable to the distribution of a blackbody $M_\mathrm{b}(\lambda)$, the temperature of this blackbody is called the distribution temperature of the emitter.

The distribution temperature is calculated from a set of absolute radiation spectrums $M_b(T,\lambda)$ of the blackbody (i.e. the Planck function value) at different temperatures using Formula (A.1). The minimum of the following function defines the distribution temperature:

$$\sum_i \left(1 - \frac{M(\lambda_i)}{a \cdot M_\mathrm{b}(\lambda_i, T)}\right)^2 = A(a,T) = \mathrm{min} \qquad (2)$$

where

$M(\lambda_i)$	is the measured radiant exitance of the emitter;
$M_\mathrm{b}(\lambda_i, T)$	is a measured or calculated blackbody radiant exitance;
λ_i	is a wavelength for which a measurement exists;
a	is a scaling factor;

The sums over the wavelength λ_i are taken for all measured values of $M(\lambda)$ at the measurement wavelengths.

The solution of Formula (2) is either directly generated or first the scaling factor a is minimised and then a separate calculation provides the minimum of

$$\sum_i \left(1 - \frac{M(\lambda_i) \cdot \sum_k \left(\frac{M(\lambda_k)}{M_\mathrm{b}(\lambda_k)}\right)}{M_b(\lambda_i) \cdot \sum_k \left(\frac{M(\lambda_k)}{M_\mathrm{b}(\lambda_k)}\right)^2}\right)^2 = A(T) = \mathrm{min} \qquad (3)$$

where the corresponding blackbody temperature is the distribution temperature of the emitter.

7.4.11 Thermal ruggedness

The thermal ruggedness of emitters is their resilience to withstand thermal shock or strong thermal gradients inside the emitter:

a) the resilience of quartz tube infrared emitters to thermal stress exceeds all relevant test conditions or operation conditions, so no test is needed;
b) for emitters that resemble a tile or brick made from refractory material, the test defined in EN 993-11 shall be used.

7.4.12 Pinching temperature of pinched emitters

Method 3) of IEC 60682:1980/AMD1:1987 and IEC 60682:1980/AMD2:1997 shall be used, as methods 1) and 2) of IEC 60682:1980 are destructive.

7.5 Radiation characteristics

7.5.1 General

The emitted radiation of a specific infrared emitter can be characterised by the following radiometric values or functions:

a) the spatial irradiance field generated by the emitter and depending on distance and angular direction from the emitter;
b) the spectral distribution of the radiant power, being a function of the emissivity and the temperature distribution of the source (refer to Annex A);
c) the spatial variation of the spectral radiant power, i.e. the spectral variation of the irradiation – this effect is negligible for most emitters;
d) total radiant power or named total radiant flux or named radiant exitance (refer to 3.2.1, 3.2.3, 3.2.4, 3.2.9),
e) the hemispherical or normal total emissivity and hemispherical or normal spectral emissivity;
f) radiance field;
g) irradiance field.

The spectrum depends on the source temperature (7.4) and the spectral emissivity of the source (Clauses A.2, C.3) and to a much smaller degree on other effects.

The spatial irradiance field on a workload position or on any other surface depends

– on the shape of the emitter,
– on the surface material and structure of the source,
– other elements that affect the distribution of radiation, like the emitter tube, fixtures inside the emitter tube, or electrodes.

The spatial irradiance field can further be affected by the applied voltage to the emitter and by the environment.

The measurement of irradiance is performed using a device as defined in 6.5.

Irradiance distribution on an intended workload position and the spectrum of the irradiance are relevant for the technical use of an infrared emitter. Thus 7.5.2 provides a test for the basic irradiation characteristic of a tubular emitter, from which the reflectivity of a reflector can be assessed by use of 7.5.3; an assessment of the irradiation on a surface of a potential workload position is given in 7.5.4, test methods for the spectrum are discussed in 7.5.5. The rated total radiant power or radiant flux and the calculation of the irradiation efficiency are given in 7.5.7 and 8.4.

7.5.2 Radial irradiation distribution of tubular emitters

The radial irradiation field is measured at rated power and in stationary condition.

The detector measuring irradiation is placed on a rotating unit that rotates the detector at constant radial distance around the emitter axis and orienting the detector so that it is always facing the emitter directly. The emitter may be rotated instead.

The measurements shall be taken with a constant angular step-width of 10° or 5°. A full circle of 360° shall be measured.

No smoothing of the data is allowed. The data may be presented on a normalised base, where the irradiance depending on angular position is divided by the average irradiation. The average irradiation is calculated using

$$\overline{E} = \frac{1}{n}\sum_{i=1}^{n} E_{\mathrm{i}}(\alpha_{\mathrm{i}}) \tag{4}$$

where

E is the irradiance;

n is the number of measurement positions;

α is the angular position.

7.5.3 Reflectivity of a tubular emitter with applied reflector

For infrared emitters of tubular geometry and with a reflector placed on one side of the emitter tube the reflectivity of the reflector shall be calculated using the data from 7.5.2 and Formula (5).

$$\rho = 1 - \frac{E_{\rho}}{\overline{E}} \cdot \frac{360°}{\alpha_{\rho}} \tag{5}$$

with

$$E_{\rho} = \sum_{m} E_i(\alpha_i) \tag{6}$$

where

ρ is the reflectivity;

m is the number of measurement positions in angular directions with a reflector;

α_{ρ} is the angle of the tubular emitter covered by a reflector.

In the case of a tubular emitter without a reflector and homogenous angular irradiation the reflectivity is zero. In the case no radiation is detected behind the reflector, Formula (5) gives a perfect reflectivity independent of the angle of the reflector-covering.

7.5.4 Planar irradiation field caused by an emitter

The irradiation caused by an emitter depends on the distance from detector to emitter and the angular orientation between emitter and detector. The following is defined for the measurement of the irradiation distribution on a surface irradiated by an infrared emitter:

a) The irradiation detector scans the irradiated field below the infrared emitter in a distance d, this can be the intended working operation distance.
b) The measurement positions on the plane of measurement shall be spaced apart at most for a length of $d/4$.
c) The measurement plane shall be at least the size of the emitter plus a distance of $2 \cdot d$ in all four spatial directions to cover the sideways irradiation caused by the emitter.
d) The measurement shall cover the complete plane unless symmetry of irradiation allows for less: measuring half of the plane or a quarter of the plane and assuming symmetry shall be stated with the measurement data.
e) No smoothing of the data shall be performed.

The detector shall be oriented so that its direction of view is perpendicular to the measurement plane.

7.5.5 Angular irradiation distribution caused by an emitter

The test defined in 7.5.2 does not provide the full data for a tubular emitter. This test only provides a specific aspect of irradiation caused. This aspect is of major interest, as it allows the prediction of the radiation field caused by one straight tubular emitter or a number of straight tubular emitters oriented in parallel. The test defined in 7.5.4 provides the irradiation caused on a surface, which usually coincides with the position of a workload.

The measurement method defined in the following list can as well be used for the measurement of the total radiant power, if a data set at a specific distance between detector and emitter on a full spherical substance is needed:

a) The emitter is placed on a goniometer such that the centre of the emitter is at the angle point of the goniometer.
b) The emitter is operated in stationary condition and at constant voltage.
c) The temperature dependent irradiation is measured using a detector with a non-wavelength dependent sensitivity. The range of constant sensitivity should at least cover the wavelength range defined in 6.5.
d) The detector is placed at a specific distance. The minimum distance is defined as being larger than the longest half axis of the emitter, because an infrared emitter can be a large source for this kind of test.

The angular irradiation distribution measured by the detector depends for the so called near field on the distance between emitter and detector. Near field is defined as a distance less than 50 times the largest diameter of the emitter, far field is defined as a larger distance.

Detailed advice on goniometric tests can be drawn from EN 13032-1 [10]; the test methods introduced there may be transferred into the infrared if a sufficient detector is used.

7.5.6 Emitted spectrum

The emitted spectrum is a function which describes how the radiant exitance (or radiance or irradiance) of infrared emitters varies with the wavelength.

The spectral radiant power of thermal emitters depends on the temperature and to a much lower extent on the temperature and wavelength dependent emissivity of the source surface. The spectrum of the source may be altered further by emitter tubes or other parts of the emitter protecting the source as these parts may absorb and emit radiation as well.

Annex A provides the basic formulas to calculate the spectral radiant power at rated voltage from the rated temperature provided by test 7.4.1.

The emitted spectrum can be measured using methods discussed in 6.6 and in Annex C.

7.5.7 Rated total radiant power

7.5.7.1 Distributed radiometric method

A comparable test is applied for the measurement of luminous flux from lamps and described in CIE-084 [11]. The following list is an application of this distributed photometric test to the infrared:

a) Ensure that the radiant surface of the emitter can be approximated as a point source relative to the detector of radiant power meter – this is the case, if the distance between emitter and detector is at least 10 times larger than the largest diameter of the emitter itself.
b) Adjust the azimuth of the emitter to the centre of the emitter.
c) Measure at every 5° between 0° to 60°, as well as every 10° between 60° to 90° relative to the axial line of the emitter.
d) Measure the radiant power (or irradiance) for each measuring point.

An irradiance measuring device (6.5) is placed on a rotating sample holder or goniometer. During the emitter and the detector relative motion, the scanning measurement is performed on the complete measurement sphere.

The total radiant power can be calculated from the above measured data according to

$$P_{\mathrm{tot}} = \frac{r^2}{S_{\mathrm{d}}} \cdot \sum_{\theta=0°}^{\theta=90°} P_\theta \cdot a_\theta = r^2 \cdot \sum_{\theta=0°}^{\theta=90°} E_\theta \cdot a_\theta \qquad (7)$$

where

P_{tot} is the total radiant power in W;

S_{d} is the responsive detector area of the radiant power-meter detector in m^2;

r is the distance between the source and the photo-surface of the detector in m;

P_θ is the average radiant power of the zonal spherical for the corresponding angle in W;

E_θ is the average irradiance of the zonal spherical for the corresponding angle in $\mathrm{W/m}^2$;

a_θ is the zonal spherical factor, given in Table D.1.

7.5.7.2 Thermal imaging method

This test applies for grey-body emitters or emitters with approximate grey-body emissivity and a near homogenous source temperature.

The average temperature on the source surface of the emitter is measured with a pyrometer or an infrared camera and calculated according to 7.4.8 and Formula (A.1).

The emissivity correction of the measuring device is set to 1. The measured temperature is interpreted as the radiation temperature or equivalent blackbody temperature.

The total radiant power of the emitter is then calculated according to

$$P_{\mathrm{tot}} = A\sigma\left(T_{\mathrm{r}}^4 - T_0^4\right) \qquad (8)$$

where

A is the surface area of the emitter source in m^2;

T_{r} is the average temperature value of the emitter source in K;

T_0 is the average temperature value of the environment in K;

σ is the Stefan-Boltzmann constant.

The rated total radiant power is calculated by an integral over the irradiance measured on the complete measurement sphere as defined in 7.5.5.

7.5.8 Irradiation reaction time

Irradiation reaction time is defined as the time after applying rated voltage to the emitter until the emitter reaches 80 % and 90 % of irradiation at stationary conditions, as well as decrease of irradiation to 50 % and 10 % after switch off.

The measurement position shall be in the intended irradiation direction of the emitter in the intended operation distance.

The emitter shall be turned to rated voltage immediately. The rise time to 80 % and to 90 % of stationary condition irradiation at rated voltage shall be stated.

The emitter is disconnected from the source after operating in continuous operation at rated voltage stationary condition. Then the time to 50 % and to 10 % of irradiation at stationary conditions is measured.

7.6 Mechanical ruggedness

7.6.1 Acceleration

Tests concerning acceleration performance of infrared emitters shall be conforming to IEC 60068-2-7 with the following exception:

Infrared emitters tend to differ strongly in their tolerance of maximum acceleration depending on their orientation to the direction of acceleration and they are usually accelerated during operation in one defined direction. Therefore, tests shall be performed for all relevant directions and results shall be stated separately. Relevant directions are the fundamental directions or axes of symmetry of the emitter, i.e. for a tubular straight emitter two directions for any 3D formed three directions are necessary.

Infrared emitters can be quite large, so linear acceleration is preferred to centrifugal acceleration.

7.6.2 Vibration

Tests to characterise the vibration performance of infrared emitters shall conform with IEC 60068-2-6 with the following exception:

Infrared emitters tend to differ strongly in their tolerance of maximum vibration depending on their orientation to the direction of acceleration. Direction of the vibrating during operation can be mainly in one preferred direction. Therefore tests shall be performed for all relevant directions and results shall be stated separately. Relevant directions are the fundamental directions or axes of symmetry of the emitter, i.e. for a tubular straight emitter two directions for any 3D formed three directions are necessary.

7.7 Lifetime of infrared emitters

7.7.1 General

The lifetime of infrared emitters with the exception of arc lamps is usually interpreted as the time elapsed after which 50 % of identical infrared emitters are still operable under the assumption that all emitters were operated as intended, never stressed throughout their lifetime and no mechanical cause for breakage occurred. Sometimes a Weibull statistics approach can be chosen to further identify when emitters tend to fault over time of operation.

In this standard, lifetime is understood as the cumulative operation time of an emitter until it no longer operates normally or provides the intended service at rated voltage under intended operation conditions.

Annex F discusses criteria that define this end of useful life. Thus any lifetime statement is only valid for a limited set of parameters. The actual lifetime of any infrared emitter can dramatically differ from the value given by the manufacturer, if any of the factors identified in Annex F differs from test conditions.

NOTE Stated lifetime for any emitter exceeding a value of 25 000 h is no longer reliable. 25 000 h amount to three years of continuous operation, Over such a long period factors outside the lifetime estimation or manufacturers experience or rare incidences like externally induced electric supply energy pulses are then the main cause of failure.

7.7.2 Criteria defining end of life

If an emitter reaches during a lifetime test one of the following states, it is supposed to have reached the end of its lifetime:

a) the emitter breaks or is otherwise irreparably damaged;
b) the sealing or pinching of the emitter tube fails or is broken;
c) the electric power at rated voltage is lower than 75 % or higher than 115 % of the rated power;
d) the conversion efficiency for total radiation (or total radiant power) is lower than 90 % of the initial value;
e) the peak wavelength of the radiant spectrum or the distribution temperature differs by more than 10 % from the rated or initial value;
f) the outside surface shows signs of severe melting, cracking, arcing or similar;
g) the electric strength of emitter under operation temperature is significantly lower than a rated value;
h) the leakage current of emitter under operation temperature significantly exceeds a rated value.

NOTE Electric strength and leakage current are strongly influenced by the temperature of insulating parts like the emitter tube and thus vary over orders of magnitude depending on the environment and the operating conditions.

7.7.3 Lifetime measurement

To get to statistically relevant numbers for

– the average electrical lifetime of a specific type of infrared emitter, or
– a Weibull statistic for the lifetime of a specific type of emitter,

a sufficient number of similar emitters shall be operated over a sufficient long time to fail at least 50 % of the emitters at constant and defined conditions. The measurement shall meet the following requirements:

a) at least 100 identical emitters shall be used for a measurement of average electrical lifetime;
b) all emitters shall be operated under identical conditions;
c) operating conditions shall be monitored during operation and storing of all involved emitters; all emitters experiencing any variation in operating conditions or storage conditions that differ from intended conditions of the test and that can affect their actual lifetime shall be discarded from the test.

If the manufacturer provides lifetime data based on such extensive measurements, this data shall include the following

– the emitter type, batch and all other means to identify it exactly;

– the number of emitters used during the measurement, the number of discarded emitters;
– the duration of the test;
– the environmental conditions of the test, i.e. the atmospheric pressure, air temperature, air velocity, cross irradiation between emitters, and all variations of these parameters as well as all other parameters necessary to repeat the measurement.

NOTE The cost of measuring equipment is usually prohibitive to operate a large number of emitters at the same time. As one year has about 7 000 h, a lifetime measurement requires some time. The energy necessary for operating 100 emitters at a rated power of 2 kW over 15 000 h amounts to 3 000 000 kWh. This is a substantial cost factor when considering measuring lifetime.

7.7.4 Induced lamp death for emitter with a tungsten coil

The accelerated lifetime test, or induced lamp death as defined in Annex D of IEC 60432-1:1999 is applicable to quartz tube emitter, halogen emitter and all other infrared emitters with a tungsten coil as source. It can shorten the time for operation of the test emitters by a factor of up to 3,5 by increasing the applied voltage to a maximum of 110 % of rated voltage. The test applies for lamps with tungsten coils for general lighting purposes only.

Great care is needed in interpreting this kind of data:

– as such an increase in voltage can cause another failure mode than operation at rated voltage;
– this test has been developed for lamps for illumination and the exponents are only valid for the usual environmental conditions of lamps inside a luminaire;
– lamps for illumination tend to have quite different coils than infrared emitters.

7.7.5 Induced lamp death for other emitter

A comparable test like the induced lamp death may be agreed on between the manufacturer and user. Basic requirements are the following:

a) an increase of operating voltage or another significant operation condition leads to shortened lifetime,
b) a clear functional relationship between the degree of degrading operating condition and lifetime has been obtained and
c) this functional relationship is sufficiently exact over a defined range to allow for a meaningful prediction.

Usually the varied operating condition is the applied voltage compared with the rated voltage. Functional dependency and the achievable error margin shall be part or the test report.

A method similar to the accelerated lifetime test included in IEC 60432-1:1999 can be chosen if the characteristics of infrared emitter are similar to incandescent lamps.

7.7.6 Lifetime statement

The manufacturer can give a lifetime statement based on experience, if he is unable or decides not to perform a lifetime measurement for a specific infrared emitter category. Such a lifetime statement shall include the following to identify the range and scope of the statement:

a) the emitter categories and all necessary means to identify them;
b) the intended purpose;
c) the environmental conditions for which the statement is valid.

The statement shall clearly state that it is not based on measurements as defined in 7.7.2 or it shall explain how measurements are used as base for the statement.

8 Emitter efficiency

8.1 General

The transfer of energy from an emitter to a workload is influenced by the following non-independent factors:

a) the conversion efficiency of electric energy into infrared radiation – see 8.2;
b) the geometry of the problem, or how much of the radiation emitted by the emitter reaches the surface of the workload – see 8.3;
c) the spectral match between the spectrum emitted by the emitter and the radiation absorbed by the workload – see 8.4;
d) the absorption of radiation by the atmosphere between emitter and workload;
e) the absorption of the spectrum reaching the surface of the workload by the workload – this depends on the geometry of the problem and on the absorptivity of the workload.

8.2 Conversion efficiency

The conversion efficiency may be approximated by use of the formulas given in Annex A as

$$\eta_{\text{conv}} \overset{(1)}{\cong} \frac{A \cdot \int_0^{\infty} \frac{c_1}{\lambda^5} \frac{\varepsilon(\lambda,T)}{\exp(c_2/\lambda\, T)-1} d\lambda}{P_{\text{el}}} \overset{(2)}{\cong} \frac{A \cdot \sigma \cdot \varepsilon(T) \cdot T^4}{P_{\text{el}}} \qquad (9)$$

where

A	is the emitting surface of the material;
c_1, c_2	are constants;
λ	is the wavelength,
T	is the temperature of the emitter in K;
$\varepsilon(\lambda,T)$	is the spectral and temperature dependent emissivity of the surface;
η_{conv}	is the transfer efficiency;
P_{el}	is the actual measured electric power in W;
σ	is the Stefan-Boltzmann constant;
$\varepsilon(T)$	is the spectrally weighted temperature dependent emissivity.

The first approximation (1) is based on the integration of the Planck Formula (A.1) from Annex A and assumes that the generated radiation is caused by a source of homogenous temperature. The second approximation (2) is based on the Stefan-Boltzmann Formula (A.2) from Annex A. It assumes that the emissivity is wavelength and temperature independent.

If the emitted spatial irradiation distribution is measured using the methods given in 7.5.7 and that data is integrated over the measurement sphere, this spectrally and spatially integrated radiation power may be used instead to calculate conversion efficiency.

8.3 Transfer efficiency

8.3.1 General

Transfer efficiency can be estimated through the amount of radiation reaching the workload divided by all radiation generated.

Optimisation of transfer efficiency is only one of the relevant issues during design of equipment, other issues are speed of processing, homogeneity of processing or energy efficiency of the complete installation.

Therefore, tests are usually performed in an installation or in a test installation as described in Annex A of IEC 62693:2013.

It may be necessary to study the interaction between emitter and workload without the interference and disturbances of a complete installation. This may be done numerically, but any calculation provides reasonable and meaningful results only if the used data represents the problem sufficiently well.

8.3.2 Simple approach

A simple method is the use of geometric radiation transfer functions for the geometric problem. A convolution of the emission spectrum with the absorption spectrum gives reasonable results for non-transmitting workloads with low reflectivity and especially for grey absorbers.

A convolution operation can be done using a spreadsheet software and sufficient wavelength resolution. Sufficient is either $0{,}1 \cdot \lambda_{max}$ or a resolution that grasps the relevant spectroscopic features of emission and absorption spectrum.

Geometric radiation transfer functions can be drawn from handbooks such as *Thermal radiation heat transfer* by Siegel and Howell [12] or from Part 1A of ECSS-E-HB-31-01:2011 [13].

8.3.3 Ray-tracing

Use of ray-tracing gives very accurate results, if

a) the geometry of the problem is well specified in the model;
b) a sufficient number of rays is used;
c) a sufficient number of different wavelength covering the complete emission spectrum is used;
d) the optical behaviour of all materials and surfaces is sufficiently well modelled.

Generally, use of a numerical method shall include a documentation that allows to make the same calculation with a different software and on a different computer without any problems.

8.4 Irradiation efficiency

Irradiation efficiency is defined by the spectral match between emitted spectrum and absorption behaviour of a workload. It is calculated using the formulas as laid out in Annex A and a known absorption spectrum of the workload material.

Annex A
(informative)

Thermal infrared radiation

A.1 General

Annex A discusses the basic concept of thermal infrared emission in so far as it is relevant for this standard and the motivation behind some requirements.

A.2 Spectral emission

The spectral emissive power of any material is governed by Planck's law ([12], [14])

$$M(\lambda,T)=\frac{c_1}{\lambda^5}\cdot\frac{\varepsilon(\lambda,T)}{\exp(c_2/\lambda T)-1} \quad \text{(A.1)}$$

where

$M(\lambda,T)$ is the spectral emissive power (i.e. spectral radiant exitance);

c_1, c_2 are constants;

λ is the wavelength,

T is the temperature;

$\varepsilon(\lambda,T)$ is the spectral and temperature dependent emissivity (i.e. spectral emissivity) of the surface.

The total emissive power (i.e. radiant exitance) or the heat flux can be calculated by using the generalised Stefan-Boltzmann equation which includes an emissivity

$$M(T)=\varepsilon(T)\cdot\sigma_{SB}\cdot T^4 \quad \text{(A.2)}$$

where

σ_{SB} is the Stephan-Boltzmann constant;

$\varepsilon(T)$ is a spectrally weighted temperature dependent emissivity (i.e. total emissivity) of the surface material.

In the case of grey emitters where $\varepsilon(\lambda,T)$ = constant, Wien's displacement law

$$\lambda_{max} = c_W/T \quad \text{(A.3)}$$

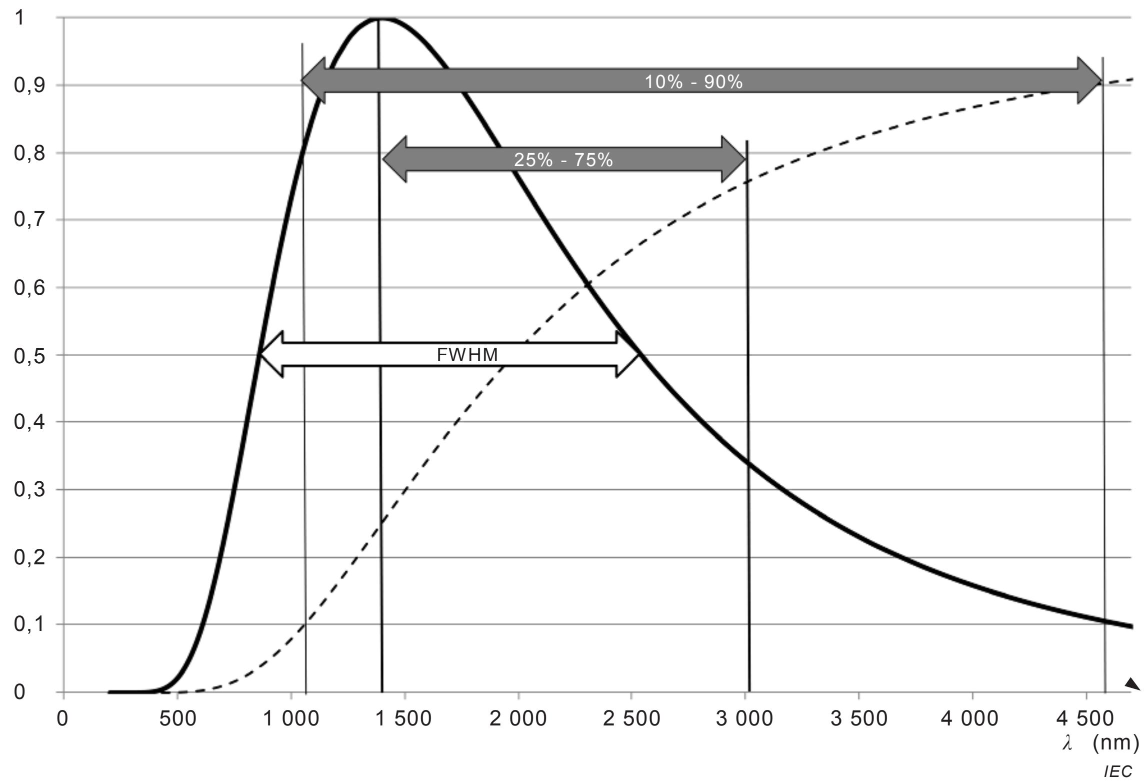
holds, where

c_W is Wien's displacement constant;

λ_{max} is the wavelength of maximum emitted power.

Figure A.1 illustrates Planck's formula for T = 1 800 °C; included are some wavelength ranges which centre around the maximum of the spectral emissive power at λ_{max} = 1 400 nm.

NOTE Another name for spectral emissive power is spectral radiant power. Another name for spectrally weighted temperature dependent emissivity is total emissivity, but the second term is usually implying that the emissivity is not temperature dependent contrary to Formula (A.3).



Key:

(solid line)	is the spectral emissive power for a temperature of 1 800 °C, a grey or black emitter and normalised for maximum emissive power;
(dashed line)	is the accumulated emitted percentage of power for the emission shown;
FWHM	is full width at half maximum of the spectral emissive power;
25 % – 75 %	is the spectral range of the central 50 % of the spectral emissive power;
10 % – 90 %	is the spectral range of the central 50 % of the spectral emissive power.

Figure A.1 – Spectral emissive power and accumulated power of a grey emitter at 1 800 °C

Wien's law (A.3) does not only connect the wavelength of maximum spectral emissive power to the temperature, but does link all relevant features of Planck's curve to the temperature. This is illustrated in Table A.1 for the percentiles of power.

Table A.1 – The generalised Wien's displacement law

%	0,1	1	10	20	25	30	40	50	60	70	80	90	99	99,9
$\lambda \cdot T/c_W$	0,383	0,500	0,757	0,916	1	1,08	1,24	1,42	1,64	1,93	2,37	3,24	7,90	17,8

From this information one draws the following conclusions:

a) it is sufficient to state the rated temperature of the emitter to give detailed information on the spectral emissive power;

b) thermal emission is quite broadband, FWHM as well as the 25 % – 75 % range cover a wavelength range $\Delta\lambda \cong \lambda_{max}$;

c) arguments that centre on spectral match between λ_{max} and some specific feature of the workloads absorption spectrum are therefore quite often misleading;

d) only for high rated temperatures is the spectral emissive power comparably small and line spectrum arguments with respect to irradiation efficiency can often be substantiated;

e) especially the long wavelength tail of Planck's function often leads to heating of the workload independent of specific features of absorption;

f) a strong argument in favour of higher rated temperature is the increase in available power density of the infrared emitter.

A.3 Emissivity

Materials used for infrared sources or emitting surfaces are usually

- refractory metals like tungsten,
- carbon,
- oxidic ceramics like silicon dioxide, alumina, zirconia, chromium oxide, but can contain a broad range of other oxides. In all cases, a high emissivity gives high emitted power at low temperature.

The spectral emissivity of these materials is well known, but the shape and structure of the emitting surface influences emissivity as well, especially the surface state

- tungsten is used in coils which leads to a near grey emissivity at about 0,5 to 0,7 for all relevant wavelengths;
- carbon filaments show very rugged surfaces with a grey emissivity between 0,9 and 1,0;
- oxidic surfaces can vary in spectral emissivity between 0,5 and 1,0.

These variations in spectral emissivity cause only small variation of the emitted spectrum due to the structure of Planck's law (A.1). To achieve meaningful observable difference of an emission spectrum to a grey emissive spectrum, a variation in spectral emissivity in the range of one order of magnitude is necessary in the 10 % to 90 % wavelength range.

A.4 Conservation of étendue

The optical area-solid angle invariant or étendue is relevant for understanding energy transfer in infrared electroheating [15]. Especially relevant and limiting is the concept of conservation of étendue for the engineering of optical systems intended for a high acceptance and transmission of power. It is one of the basic laws of physics. It states that an optical funnel is not feasible and limits the available power density on any surface irradiated by thermal sources to a value near the emitted power density of the source.

Annex B
(informative)

Infrared classification not used in this standard

As many different names and concepts are used in infrared emitter technology, this Annex B gives a classification not used in this standard, but known to industry. This standard uses a classification that conforms to IEC 62471:2006 [3] and definition 3.1.1. An alternative, based on terminology according to IEC 60050-841:2004 is presented in Table B.1.

Table B.1 – Classification based on terms defined in IEC 60050-841:2004

Spectral band (peak wavelength in which)	Rated temperature of thermal emitter	Common category	Comments
shortwave infrared radiation (IEV 841-24-04) 780 nm to 2 000 nm	more than 1 180 °C	– halogen emitter – tungsten quartz tube emitter – arc lamps – graphite heating rods – molybdenum disilicide heating elements	this includes all IR-A and large parts of IR-B
mediumwave infrared radiation (IEV 841-24-03) 2 000 nm to 4 000 nm	450 °C to 1 180 °C	– ceramic emitter – heating wire made from nickel-chromium alloys – nichrome – heating wire made from alloys of chromium, aluminum and iron – quartz tube emitter with heating wire coil (Cr, Al, Fe) – quartz tube emitter with carbon filament – quartz tube emitter with tungsten coil – silicon carbide heating rods	this includes parts of IR-B and parts of IR-C
longwave infrared radiation (IEV 841-24-02) 4 000 nm to 1 mm	less than 450 °C	– metal tube – ceramic emitter – electroheating film emitter	this wavelength range is not in the scope of this standard

Annex C
(normative)

Measurement of spectral emission and spectral data of the emitter

C.1 General

The following comparative method for measuring of spectral data is recommended in this standard, as this method directly integrates the necessary calibration into the measurement and thus reduces error sources caused through absorption from atmospheric gases or drift of the equipment. Thus the temperature dependent emitted power as defined in Formula (A.1) can be measured with a simple approach.

C.2 Comparative method

A high quality blackbody operating preferably near the rated temperature of the measured surface is used as direct reference. Its temperature shall be known to ± 2 K and be kept at ± 2 % temperature variation throughout the measurement. Preferred are ITS90 [16] blackbodies with an emissivity exceeding 99 %.

The measurement is performed at stationary conditions of the emitter.

The spectral radiant exitance is measured spectrally and resolved by use of a grating monochromator. The spectral resolution of the grating monochromator shall at least be 1 % of the peak wavelength of the blackbody (e.g. 10 nm for λ_{max} = 1 000 nm). A pyroelectric detector is preferably used as a sensor in the infrared and a silicon detector is used as a sensor in the visible and UV.

The temperature of the blackbody is set close to the expected rated or maximum temperature of the test sample. The relative radiation spectra of the blackbody and of the tested emitter are measured under identical conditions either one after the other, or preferably by measuring both for each measurement wavelength.

The wavelength dependent spectral radiant exitance can be calculated by

$$M(\lambda,T) = \frac{S(\lambda,T)}{S_{\text{b}}(\lambda;T_{\text{b}})} M_{\text{b}}(\lambda;T_{\text{b}}) \tag{C.1}$$

where

$M(\lambda;T)$ is the spectral radiant exitance of the tested emitter in W/(cm^2·µm);

$M_{\text{b}}(\lambda;T_{\text{b}})$ is the spectral radiant exitance of the blackbody in W/(cm^2·µm);

$S(\lambda;T)$ is the signal output of the measuring system for the tested emitter;

$S_{\text{b}}(\lambda;T_{\text{b}})$ is the signal output of the measuring system for the reference blackbody;

T_{b} is the temperature of the blackbody

if the measurement signal is a voltage and this voltage is a linear function of the irradiance.

C.3 Measurement of the spectral emissivity

The spectral emissivity is defined as the ratio between the spectral radiant flux emitted by a surface and the spectral radiant flux emitted by a blackbody being at the same temperature as the surface. The surface may be the source of the emitter.

The spectral emissivity is measured by comparing the irradiation of the measured surface with the irradiation caused by a blackbody of identical temperature usually through using the comparative method as defined in Clause C.2. It is calculated using

$$\varepsilon(\lambda,T)=\frac{S(\lambda,T)}{S_{\mathrm{b}}(\lambda,T)}\varepsilon_{\mathrm{b}}(T) \tag{C.2}$$

where

$\varepsilon_{\mathrm{b}}(T)$ is the effective emissivity of the blackbody.

It is assumed that all geometrical effects can be neglected.

The surface temperature of the emitter may be controlled and measured by precision temperature controllers with contact thermometers or thermocouples.

Annex D
(informative)

Zonal spherical factors

The zonal spherical factors needed in 7.5.7 and provided in Table D.1 are derived using the geometry of Figure D.1.

Table D.1 – Zonal spherical factors and corresponding angles

Angular range in °	Zonal spherical factor $\alpha_\theta/10^{-2}$
0 – 5	2,39
5 – 10	7,15
10 – 15	11,86
15 – 20	16,49
20 – 25	20,97
25 – 30	25,31
30 – 35	29,46
35 – 40	33,37
40 – 45	37,03
45 – 50	40,41
40 – 45	37,03
45 – 50	40,41
50 – 55	43,39
55 – 60	46,23
60 – 70	99,26
70 – 80	105,79
80 – 90	109,11

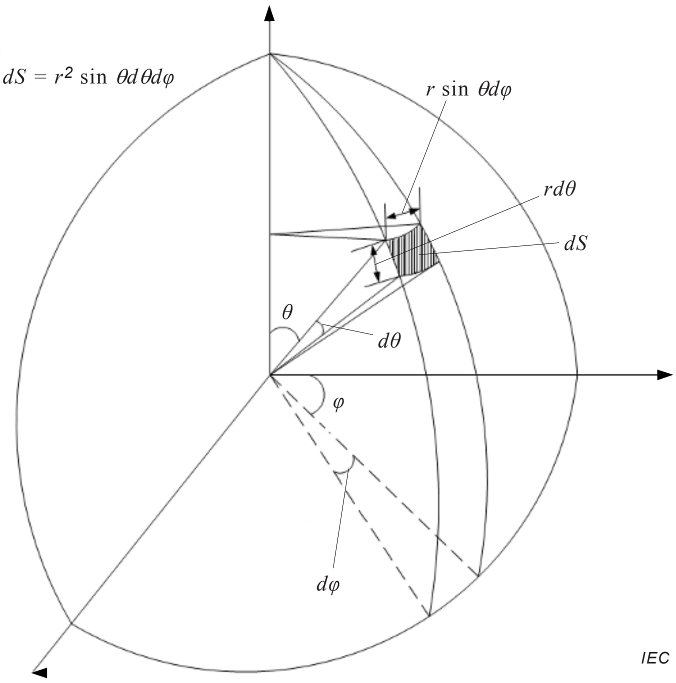


Figure D.1 – Illustration of the measurement geometry for zonal spherical factors

The irradiance on a spherical surface which fully encircles the emitter amounts to

$$E_{\text{tot}} = \iint E(\theta,\varphi)\, dS = \int_{\varphi=0}^{2\pi} \int_{\theta=0}^{\frac{\pi}{2}} E(\theta,\varphi) r^2 \sin\theta\, d\theta\, d\varphi \tag{D.1}$$

where

$E(\theta,\varphi)$ is the irradiance on a sphere with the angular coordinates (θ,φ);

r is the radius of the sphere.

The distributed radiometric method is based on the assumption that $dE = E(\theta,\varphi)\, dS$. So if the spherical surface is divided into a number of zonal spherical rings in accordance with the different angles θ

$$E_{\text{tot}} = \iint E(\theta,\varphi) dS = \int_0^{2\pi} \int_0^{\frac{\pi}{2}} E(\theta,\varphi) r^2 \sin\theta\, d\theta\, d\varphi = r^2 \int_0^{\frac{\pi}{2}} E_\theta (2\pi \sin\theta) d\theta = r^2 \sum_{\theta=0}^{\theta=90^\circ} E_\theta \alpha_\theta \tag{D.2}$$

where

E_θ is the average irradiance on a zonal spherical for the corresponding angle;

α_θ is the zonal factor;

Annex E
(informative)

Distribution of measurement positions for temperature measurements

E.1 Reference operating temperature

The reference operating temperature corresponds to the total radiant power of the emitter; it usually differs from the rated temperature in 7.4.1 and is therefore included. It is defined as the average temperature measured on the effective emitting surface of the emitter.

The reference operating temperature is measured at rated voltage and standard environmental condition. Information on reference operating temperature measurements at deviating environmental conditions should include a statement describing the conditions of measurement. The measurement should be performed at stationary conditions. The reference operating temperature measuring points on the surface of emitters are indicated in 7.4.9.

In case of emitters where the source is clearly not the outer surface of the emitter (for example quartz tube emitter), the emitted radiation comes at the same time from the surface and the internal source (e.g. the filament of the emitter). In this case, the reference operating temperature may be defined as the distribution temperature.

In accordance with radiometric definitions, when the spectral radiant power distribution of the sample in a specific spectral range is identical (or similar) to the distribution of the blackbody, the blackbody temperature is called the distribution temperature of the sample.

The measurement method for distribution temperature as given in 7.4.10 can be used.

E.2 Temperature distribution coefficient

The temperature measuring points on the surface of emitters can be equally spaced over the surface of the emitter or non-equally spaced, depending on the aim of the tests.

The temperature of the geometric centre of the source is the highest measured temperature in many cases. Therefore, the geometric centre is artificially specified as a reference point for the measurement.

– The geometric centre of a cylinder surface can be determined when it is unfolded to become a rectangular plane.
– The radiant surface is the effective emitting outer surface of the emitter. Therefore the geometric centre is artificially specified as a reference point of measurement.

The temperature distribution coefficient of the temperature can be calculated using

$$a = \frac{1}{T_Z}\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(T_i - T_Z\right)^2} \tag{E.1}$$

where

T_Z is the temperature value at the geometrical centre of the radiant surface in K;

T_i is the temperature value of the i-th measurement position in K;

n is the number of measurement positions.

Annex F
(informative)

End of life criteria for infrared emitter

The lifetime of an individual infrared emitter as well as the lifetime of a batch of emitters is affected at least by one of the following factors:

– a variation in production parameters during manufacturing of emitters intended to be identical, for example re-crystallisation of tungsten wire prior to use;
– a variation in the materials used for manufacturing of emitters intended to be identical;
– vibration, shock or acceleration of the emitter when transported, stored or idle;
– vibration, shock or acceleration of the emitter during operation;
– exposure to corrosive gases, dust, dirt or liquids during transport, storage and operation;
– atmospheric pressure when operating, vacuum conditions;
– temperature of the emitter or the emitter surface affected inter alia by gas temperature, gas movement, temperature of and irradiation from surrounding surfaces or the charge, irradiation from other infrared emitters;
– mechanical stress due to mounting or incorrect mounting;
– cycling operation of the emitter – number of cycles, temperature difference in cycle;
– robustness of the emitter itself depending on physical parameters and material strength;
– actual line voltage including voltage fluctuations;
– actual operating power setting of the emitter;
– operation errors and equipment faults;
– unavoidable external influences such as lightning strokes near the equipment causing field-waves or pulses to the equipment.

Therefore any lifetime statement is only valid for a limited set of parameters kept constant during a test.

Table F.1 lists instantaneous and usually clear indications that an emitter is no longer operating as intended.

Table F.2 lists gradual degradations that can lead to the point where the emitter is no longer able to perform as necessary for the process or as intended, but can strictly speaking be still operating.

Table F.1 – Instantaneous end-of-life

Failure	Description	Applicable	Root causes
electric	the moment, when resistivity of the emitter increases dramatically; usually when the filament or other conducting parts of the emitter break or fail	all emitter types	
mechanic	the moment, when the emitter breaks leading to failure of emission	all emitter types	
emitter tube	the moment, when the emitter tube loses integrity and air comes into contact with the filament, leading to electric failure	sealed emitter with for example tungsten or carbon filaments	devitrification, touching the emitter tube, tube blackening and subsequent overheating of the tube causing deformation (blow out)

Table F.2 – Gradual degradation

Degradation	Description	Applicable	Root causes
tube blackening[1]	The inner surface of the tube becoming opaque over time – radiation emitted by the filament is absorbed on this layer. A clear limit is hard to distinguish or to test for.	quartz tube emitter	evaporation of material from the filament
reflector	The reflector becomes less opaque and loses reflectivity on its functional side – accumulation of dirt on the outside may not be degrading. A clear limit is not defined. Reflectivity may be tested and assessed.	all emitter types, where reflectors are an integral part of the infrared emitter	In the case of gold reflectors it may be caused by a loss of the adhesion promoting elements from the gold layer above a specific temperature and thus indicates insufficient cooling.
emitter tube	The tube becomes opaque – radiation emitted by the filament is scattered diffusely on this layer and will be absorbed as well. Hard to assess, limits are not well defined.	quartz tube emitter	onset of devitrification of the tube or by transport of quartz glass of the tube
filament deformation	A variation filament geometry or coil pitch – leading to a variation of emitted power over the length of the emitter. Hard to assess, limits are not defined as they will depend on the process and equipment.	all emitter with a filament	
[1] A slight loss of electric power consumption is observed in tungsten coil emitter due to the increase of the filament temperature. The increasing temperature of the emitter tube in combination with absorption of radiation emitted from the filament can lead to a shift of emission to longer wavelength and an increased loss by convection. Thus radiation output decreases over time.			

Annex G
(normative)

Cold state resistivity and rated power

G.1 General

This standard does not permit the use of cold-state resistivity for the estimation of rated power or other electric values of infrared emitter. Nonetheless, if a manufacturer intends to use this approach, Annex G provides minimum requirements to achieve meaningful data.

Major technical issues are:

– measurement of cold state resistivity tends to provide systematically overstated values caused by neglected external contributions dominating at ambient temperature;
– the use of different equipment or variation on measurement process will inevitably result in non-comparability of results;
– estimating the rated power from cold-state resistivity will result in systematically too low values;
– the established connection between cold-state resistivity and power will deteriorate with ageing.

G.2 Measuring with high accuracy for comparison

Independently of the feasibility of using cold state resistivity of an infrared emitter for estimation of rated power, the following defines minimum requirements for a measurement that enables comparison of data between the manufacturer and user.

For each emitter the rated power and the resistivity at room temperature are established. To make measurements comparable and reproducible, the measuring equipment shall be sufficiently exact, it shall be calibrated regularly, and the manufacturer and user shall agree on comparable measurement methods:

– Measurement accuracy for voltage over the emitter shall be class 1 or better.
– Measurement accuracy for current shall be class 1 or better.
– Resistivity measuring equipment shall use a 4 point probe and be class 1 or better.
– Calibration intervals shall not exceed one year.
– A regular round robin test is mandatory.

It is preferred that all parties involved use the same measuring equipment.

The resistivity shall be measured

a) at constant environmental temperature, usually 20 °C ± 3 °C;
b) after the emitter has rested at this temperature over at least one hour without being touched or energised;
c) the temperature needs to be kept constant and to be monitored. The temperature of the emitter shall be part of the measurement report.

G.3 Temperature influences on measurement accuracy

The temperature dependent conductivity of all metallic parts of an emitter, for example coil, internal leads, foils, external leads, cause errors in the cold state resistivity measurement if the temperature is varied. For commonly used materials in emitter manufacturing like tungsten and molybdenum, a linear dependency between temperature and resistivity is a good estimation. Thus any error in temperature of 3 K at room temperature of approximately 293 K gives an error of 1,0 %. Measuring resistivity of an emitter that is not at the defined test temperature can easily provide an error exceeding some 10 %.

The resistivity of the coil is only part of the overall resistivity of an emitter. Small contributions come from the electrical leads, the lead through at the pinching where very small cross sections prevail and from inner connectors inside the emitter tube. These internal contributions can easily add some 10 % to the overall resistivity of the emitter.

Some electric contacts inside an emitter can contribute substantially to the overall resistivity. Resistivity can even depend on voltage applied, thus emitters having no conductivity at all in the cold state can operate very well.

G.4 Emitter manufacturing effects

The manufacturing process for emitter is usually optimised to provide a specific rated power. The resistivity of the filament can usually only be optimised for one specific voltage as resistivity depends on the following parameters:

– the actual temperature,
– the geometry of the filament, usually determined through wire diameter, pitch and diameter of the mandrel,
– the material used including its specific composition;
– manufacturing history of parts determined through mechanical rework and heating steps,
– specifics of the manufacturing process including atmosphere at heating steps.

G.5 Error contributions

The following contributes to the overall error estimation of rated power from measured cold state resistivity:

a) a mismatch between actual source temperature and rated temperature – a difference exceeding 5 % is realistic in view of the methods for measuring rated power;
b) the specific electric resistivity of the tungsten wire used in emitter manufacturing varies depending on material and manufacturing by up to 7 % from the specific electric resistivity of pure tungsten as given in the literature;
c) the ageing of filaments over the emitter lifetime affects resistivity;
d) slight changes in filament geometry are common even in a single batch, resulting in a variation of the rated temperature for each single emitter – contributing another 5 % of error.

Thus an error between 8 % under best conditions and up to 20 % is expected between estimated and true values.

Bibliography

[1] IEC 60519-1:2010, *Safety in electroheating installations – Part 1: General requirements*

[2] IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

[3] IEC 62471:2006, *Photobiological safety of lamps and lamp systems*

[4] VDI/VDE 3511 series, *Temperature measurement in industry*

[5] CIE 063:1984, *The Spectroradiometric Measurement of Light Sources*

[6] CIE 130:1998, *Practical Methods for the Measurement of Reflectance and Transmittance*

[7] CIE 149:2002, *The Use of Tungsten Filament Lamps as Secondary Standard Sources*

[8] IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

[9] CIE 114/4:1994, *CIE Collection in Photometry and Radiometry – Distribution temperature and ratio temperature*

[10] EN 13032-1:2004, *Light and lighting – Measurement and presentation of photometric data of lamps and luminaires – Part 1: Measurement and file format*

[11] CIE 084:1989, *The Measurement of Luminous Flux*

[12] R. Siegel, J.R. Howell, M.P. Pinar Menguc: *Thermal radiation heat transfer*. Taylor & Francis, Philadelphia: 1992

[13] ECSS-E-HB-31-01_Part 1A, *Thermal design handbook – Part 1: View factors*. European Cooperation for Space Standardisation, Noordvijk: 2011. (available at http://ecss.nl/forums/ecss/dispatch.cgi/publications/showFile/100198/d20111214144956/No/ECSS-E-HB-31-01_Part1A.pdf)

[14] M.M. Modest: *Radiative heat transfer*. Academic Press, Oxford: 2003

[15] R. Winston, J.C. Miňano, P. Benítez: *Nonimaging Optics*. Elsevier, Amsterdam: 2005

[16] ITS90, *International Temperature Scale of 1990* (available at http://www.its-90.com)

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™