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Industrial process control devices – Radiation thermometers —

Part 1: Technical data for radiation thermometers

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National foreword

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Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion to an international standard. A review of this publication will be initiated not later than three years after its publication by the international organization so that a decision can be taken on its status. Notification of the start of the review period will be made in an announcement in the appropriate issue of Update Standards.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international Standard, to extend the life of the Technical Specification or to withdraw it. Comments should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

The UK participation in its preparation was entrusted by Technical Committee GEL/65, Measurement and control, to Subcommittee GEL/65/2, Elements of systems. A list of organizations represented on this committee can be obtained on request to its secretary.

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INDUSTRIAL PROCESS CONTROL DEVICES – RADIATION THERMOMETERS –

Part 1: Technical data for radiation thermometers

1 Scope

This Technical Specification applies to radiation thermometry. It defines the technical data, i.e. metrological data to be given in data sheets and operating instructions for radiation thermometers with one wavelength range and one measurement field, to ensure that the data and terminology are used consistently.

Technical data for radiation thermometers are frequently given using terms whose meaning is not clear and therefore open to misinterpretation. Moreover, the data are given for measuring conditions which are not standardised. Often, influence parameters and mutual interdependencies of technical data are not given. As a result, the user cannot easily compare the technical design and performance data of radiation thermometers and tests for compliance with the manufacturer's specifications are difficult to carry out.

The purpose of this Technical Specification is to facilitate comparability and testability. Therefore, unambiguous definitions are stipulated for stating technical data under standardised measuring conditions.

NOTE 1 Infrared ear thermometers are excluded from this Specification.

NOTE 2 It is not compulsory for manufacturers and sellers of radiation thermometers to include all items given in this Specification for a specific type of radiation thermometer. Only the relevant data should be stated and should comply with this Specification.

2 Normative references

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

Guide to the Expression of Uncertainty of Measurement (1995) [BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML]

International Vocabulary of Basic and General Terms in Metrology (1993) [BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML]

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
measuring temperature range
temperature range for which the radiation thermometer is designed

3.1.2
measurement uncertainty (accuracy)
parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand

3.1.3
noise equivalent temperature difference
parameter which indicates the contribution of the measurement uncertainty in °C, which is due to instrument noise

3.1.4
measuring distance
distance or distance range between the radiation thermometer and the target (measured object) for which the radiation thermometer is designed

3.1.5
field-of-view
usually circular, flat surface of a measured object from which the radiation thermometer receives radiation

3.1.6
distance ratio
ratio of the measuring distance to the diameter of the field-of-view when the target is in focus

3.1.7
size-of-source effect
difference in the radiance- or temperature reading of the radiation thermometer when changing the size of the radiating area of the observed source

3.1.8
emissivity setting
the emissivity of a surface is the ratio between the radiation emitted from this surface and the radiation from a blackbody at the same temperature. The emissivity describes a thermo-physical material characteristic, which in addition to the chemical composition of the material may also be dependent on the surface structure (rough, smooth), the emission direction as well as on the observed wavelength and the temperature of the measured object.

In most measuring situations a radiation thermometer is used on a surface with an emissivity significantly lower than 1. For this purpose most thermometers have the possibility of adjusting the *emissivity setting*. The temperature reading is then automatically corrected

3.1.9
spectral range
parameter which gives the lower and upper limits of the wavelength range over which the radiation thermometer operates

3.1.10
influence of the internal instrument or ambient temperature (temperature parameter)
parameter which gives the additional uncertainty of the measured temperature value depending on the deviation of the temperature of the radiation thermometer from the value for which the technical data is valid after warm-up time and under stable ambient conditions

3.1.11
influence of air humidity (humidity parameter)
parameter which gives the additional uncertainty of the measured temperature value depending on the relative air humidity at a defined ambient temperature

3.1.12
long-term stability
reproducibility of measurements repeated over a long time period

3.1.13
short-term stability
reproducibility of measurements repeated over a short time period (several hours)

3.1.14
repeatability
twice the standard deviation of measurements repeated under the same conditions within a very short time span (several minutes)

3.1.15
interchangeability
maximum deviation between the readings of two instruments of the same type operating under identical conditions divided by two

3.1.16
response time
time interval between the instant of an abrupt change in the value of the input parameter (object temperature or object radiation) and the instant from which the measured value of the radiation thermometer (output parameter) remains within specified limits of its final value

3.1.17
exposure time
time interval necessary during which an abrupt change in the value of the input parameter (object temperature or object radiation) has to be present, such that the output value of the radiation thermometer reaches a given measurement value

3.1.18
warm-up time
time period needed after switching on the radiation thermometer for the radiation thermometer to operate according to its specifications

3.1.19
operating temperature range and air humidity range
permissible temperature range and humidity range within which the radiation thermometer may be operated. For this temperature range and humidity range the specifications are valid

3.1.20
storage and transport temperature range and air humidity range
permissible ambient temperature range and humidity range within which the radiation thermometer may be stored and transported without suffering permanent change

3.2 Abbreviations

FWHM: Full width at half maximum

NETD: Noise equivalent temperature difference

SSE: Size-of-source effect

4 Technical data

4.1 Types of technical data

Two types of technical data have to be distinguished: metrological data and equipment features. The metrological data relate to the metrologically relevant values measured with a radiation thermometer, whereas the equipment features are mainly important for operation and convenience in the use of the equipment.

4.1.1 Metrological data

The following metrological data are used to describe the characteristics of a radiation thermometer:

– measuring temperature range (3.1.1)
– measurement uncertainty (accuracy) (3.1.2)
– noise equivalent temperature difference (NETD) (3.1.3)
– measuring distance (3.1.4)
– field-of-view (target area, measurement field) (3.1.5)
– distance ratio (distance factor) (3.1.6)
– size-of-source effect (SSE) (3.1.7)
– emissivity setting (3.1.8)
– spectral range (3.1.9)
– temperature parameter (3.1.10)
– humidity parameter (3.1.11)
– long-term stability (3.1.12)
– short-term stability (3.1.13)
– repeatability (3.1.14)
– interchangeability (3.1.15)
– response time (3.1.16)
– exposure time (3.1.17)
– warm-up time (3.1.18)
– operating temperature range and air humidity range (3.1.19)
– storage and transport temperature range and air humidity range (3.1.20)

Relevant parameters for the particular metrological data, e.g. measuring conditions, influence parameters and mutual interdependences shall be given.

Since several metrological data of a radiation thermometer depend on the emissivity setting of the instrument, they shall always be given for an emissivity setting of 1, if not stated otherwise. For radiation thermometers with an internal fixed emissivity setting different from 1, the specifications shall be given for the standard setting of the instrument and the emissivity value shall be stated. The measuring temperature range (3.1.1), the measurement uncertainty (3.1.2) and the noise equivalent temperature difference (3.1.3) of a radiation thermometer strongly depend on the emissivity setting of the radiation thermometer.

4.1.1.1 Measuring temperature range

4.1.1.1.1 General

The measurement uncertainty remains within the specified limits for the following temperature range.

NOTE Sometimes it is useful to state additionally a wider "indicating temperature range" over which the thermometer will display a temperature but its specifications are not guaranteed.

4.1.1.1.2 Examples of data

Measuring temperature range:

-50 C to 1 000 °C

or

400 °C to 2 500 °C for the emissivity range 0,1 to 1,0

4.1.1.2 Measurement uncertainty (accuracy)

4.1.1.2.1 General

The value of the measurement uncertainty shall be given together with the measurement result (see the *Guide to the Expression of Uncertainty of Measurement*).

NOTE Where the measurement result M and the measurement uncertainty U are established, the value of the measurand lies with high probability within the limits $M - U$ and $M + U$. The measurement uncertainty should be stated as U, with a confidence level of approximately 95 % (expanded uncertainty, coverage factor $k = 2$).

The measurement uncertainty should be quoted with respect to the International Temperature Scale (currently ITS-90) – i.e. the uncertainty should include both the dispersion of the instrument readings with respect to the calibration artefacts used and the uncertainty in the traceability of these calibration artefacts to the ITS-90. Alternatively, the two contributions may be stated separately.

The frequently-used term "accuracy" is a qualitative concept and should not be used with numerical details. It generally signifies the closeness of the agreement between the result of a measurement and the value of the measurand (see the *International Vocabulary of Basic and General Terms in Metrology*).

4.1.1.2.2 Required parameters

The measurement uncertainty depends on the confidence level (a confidence level of approximately 95 % should be given), the measured temperature, the ambient temperature, the internal temperature of the radiation thermometer, the air humidity, the source diameter and the field of view (respectively the measurement distance), therefore these parameters are to be stated.

To simplify the uncertainty statement and make it more comparable, standardised measurement conditions shall be used as far as possible: The measurement uncertainty shall be stated for a confidence level of approximately 95 % and shall be valid over the complete specified operating temperature range and air humidity range (3.1.19), if not stated otherwise. Alternatively it shall be stated for: Confidence level approximately 95 %, ambient temperature 23 °C, relative air humidity of 50 % at 23 °C.

NOTE Radiation thermometers often cover a wide measuring temperature range and the radiance signal strongly increases with the target temperature. Uncertainties in temperature measurement arise from drift and noise. The noise contribution is often higher at the bottom of the temperature range and typically insignificant over most of the temperature range. For a complete specification manufacturers should provide the measurement uncertainty sampled across the complete measuring temperature range (3.1.1). This may be done by a table (see Table 1 and Table 2).

4.1.1.2.3 Examples of data

Measurement uncertainty:

0,5 °C + 0,2 % of the measured value in °C at a confidence level of approximately 95 %, over the complete measuring temperature range, over the complete instrument operating temperature and air humidity range, a source diameter of 60 mm (with a surrounding area at t = 23 °C) and over the complete measuring distance

or

0,5 °C at a confidence level of approximately 95 %, a measured temperature of 100 °C, an internal temperature of the instrument from 0 °C to 60 °C, a relative air humidity of 50 % at 23 °C, a source diameter of 60 mm (with a surrounding area at t = 23 °C) and a distance of 1 m

or

Table 1 – Measurement uncertainty (example 1)

Measured temperature °C	Uncertainty (95 % confidence level) °C	Internal temperature range °C	Ambient conditions	Source diameter mm	Measuring distance m
100	0,8	0 – 60	23 °C / 50 % RH	30	1
100	0,5	0 – 60	23 °C / 50 % RH	60	1
500	1,5	0 – 60	23 °C / 50 % RH	30	1
500	1,0	0 – 60	23 °C / 50 % RH	60	1
900	2,6	0 – 60	23 °C / 50 % RH	30	1
900	2,0	0 – 60	23 °C / 50 % RH	60	1

or

Table 2 – Measurement uncertainty (example 2)

Measured temperature °C	Uncertainty (95 % confidence level) °C	Internal temperature range °C	Ambient conditions	Source diameter mm	Measuring distance m
100	0,5	0 – 60	23 °C / ≤ 50 % RH	60	1
100	0,6	0 – 60	23 °C / > 50 % RH	60	1
500	1,0	0 – 60	23 °C / ≤ 50 % RH	60	1
500	1,2	0 – 60	23 °C / > 50 % RH	60	1
900	2,0	0 – 60	23 °C / ≤ 50 % RH	60	1
900	2,4	0 – 60	23 °C / > 50 % RH	60	1

4.1.1.3 Noise equivalent temperature difference (NETD)

4.1.1.3.1 General

Noise occurs in all electrical equipment. A sufficiently large signal-to-noise ratio shall be realised for each quantitative measurement. With spectral or band-pass radiation thermometers, the signal-to-noise ratio is basically improved by increasing the response time (integration time). The noise is highly dependent on the particular signal processing. In contrast to the other metrological data, the confidence interval in this case is 68,3 % (standard uncertainty, k = *1*).

For low cost instruments the NETD may be limited by the resolution of the instrument.

The NETD is generally largest at the lowest temperature of the measuring temperature range. For more information on the NETD the manufacturer should be contacted.

4.1.1.3.2 Required parameters

The measured temperature and the response time (3.1.16) are to be stated with the NETD. For some instruments the NETD depends on the instrument- or ambient temperature. For these instruments the instrument- or ambient temperature also has to be stated.

4.1.1.3.3 Examples of data

Noise equivalent temperature difference:

> *0,1 °C (20 °C / 0,25 s)*
>
> *at a measured temperature of 20 °C and response time of* $t_{R90\%}$ *= 0,25 s*

or

> *0,1 °C (20 °C / 100 Hz to 1 kHz)*
>
> *at a measured temperature of 20 °C and after the signal has passed through a band pass filter from 100 Hz to 1 kHz*

4.1.1.4 Measuring distance

4.1.1.4.1 General

For the distance or distance range specified in 4.1.1.4.3, the specifications are valid if not stated otherwise.

NOTE With the measuring distance the field-of-view (3.1.5) and the size-of-source effect (3.1.7) change. Therefore the manufacturer should additionally provide a graph or equation showing the field-of-view as a function of the measuring distance.

4.1.1.4.2 Required parameters

It has to be stated from which part of the radiation thermometer the distance to the target has to be measured.

NOTE Stating the measuring distance from the front lens should be avoided, as it is impractical.

4.1.1.4.3 Examples of data

Measuring distance:

> *385 mm from the red mark on the objective tube*

or

> *200 mm to 1 000 mm from the front edge of the objective tube*

4.1.1.5 Field-of-view

4.1.1.5.1 General

Its magnitude is determined by the optical components in the radiation thermometer. As the field-of-view is not sharply defined, it is necessary to state the diameter of the field-of-view at which the signal has dropped to a certain fraction of its total integrated value (hemispherical value) (see first three examples in 4.1.1.5.3).

Other synonymous terms used for the field-of-view are target area, target size and measurement field.

NOTE The transfer function between the measured radiation (input parameter) and temperature (output parameter) is non-linear. As an example the change in indicated temperature corresponding to a 1 % change in the radiation exchange with a radiation thermometer is given in Annex A. The field-of-view is therefore either defined for the fraction of measured radiation or, for instruments which only read directly in temperature, it is necessary to specify a change in the measured temperature in °C at a given temperature for the field-of-view in comparison to the total integrated value (hemispherical value).

4.1.1.5.2 Required parameters

As the field-of-view value depends on the stated fraction of signal to its maximum value (hemispherical value) and usually on the measuring distance (3.1.4), it is necessary to state the measuring distance in addition to the fraction. The fraction value should be at least 90 %; typical values are 90 %, 95 % and 99 %.

The relation between the field-of-view and the measuring distance should be shown by an equation or a figure.

As an alternative, the distance ratio (3.1.6) can be used, specified as the measuring distance divided by the diameter of the field-of-view.

For instruments which only read in temperature, it is necessary to specify with the field-of-view the change in the measured temperature in comparison to the total integrated value at the specified measured temperature. As a minimum these values should be given for the top, middle and bottom of the temperature range (see fourth example in 4.1.1.5.3).

The complete information would be a graph, which shows the signal or temperature versus source size (see size-of-source effect 3.1.7).

NOTE For some radiation thermometers, especially for high temperature instruments, it is impracticable to relate the field-of-view to a hemispherical value. In this case it is allowed to relate the given field-of-view to a larger source (e.g. twice as large in area as the field-of-view) (see fifth example in 4.1.1.5.3).

The area of the source must always be given. Since the field-of-view and the size-of-source effect are strongly related see also 3.1.7.

4.1.1.5.3 Examples of data

Field-of-view:

3,4 mm diameter (90 %), measuring distance: 400 mm

or

4,0 mm diameter (95 %), measuring distance: 400 mm

or

7,0 mm diameter (99 %), measuring distance: 400 mm

or

4,0 mm diameter (1,7 °C at 100 °C, 6 °C at 400 °C, 12 °C at 700 °C), measuring distance: 400 mm

or

4,0 mm diameter (5 % increase in measured radiation when the radiation source is twice as large in area as the field-of-view), measuring distance: 400 mm

4.1.1.6 Distance ratio

4.1.1.6.1 General

Another synonymous term used for the distance ratio is “distance factor”.

4.1.1.6.2 Required parameters

For variable focus instruments the distance ratio should be specified for a measuring distance of 1 m, if this lies within the focusing range. If it does not lie within the focusing range, then a suitable distance within the focusing range should be chosen.

4.1.1.6.3 Examples of data

Distance ratio:

120:1 (90 %), measuring distance: 1 m

or

150:1 (95 %), measuring distance: 1 200 mm

4.1.1.7 Size-of-source effect (SSE)

4.1.1.7.1 General

Imperfections in the optical components, interelement reflections and scatter lead to a blurring of the field-of-view of a radiation thermometer. Therefore, a radiation thermometer with an ideally sharp field-of-view profile is not realizable and in practice the signal of a radiation thermometer is dependent of the size of the observed source (size-of-source effect). To describe the SSE, the difference in the radiance- or temperature reading of the radiation thermometer when changing the size of the radiating area of the observed source shall be stated. The source must have a stable and homogenous radiance within this area (i.e. the temperature and emissivity of the source shall not change when changing the size of the radiating area or such changes have to be corrected). The complete information would be a graph, which shows the signal or temperature reading versus source size (size-of-source effect).

To simplify the SSE statement and make it more comparable, the following measurement conditions shall be used as far as possible: The SSE is to be stated at a given measuring distance, measured temperature and ambient temperature, when observing a target with the area of the nominal field-of-view and twice the area of the nominal field-of-view or more than twice the area of the nominal field-of-view. In the later case, the area should be specified.

NOTE The SSE is either defined as the relative change in the observed radiance or, for instruments which only read in temperature, as the absolute change in the measured temperature at a given temperature, when changing the observed target area. Since the latter definition depends on the source temperature it is necessary to state the SSE at the top, middle and bottom temperatures of the measuring temperature range.

4.1.1.7.2 Required parameters

With the size-of-source effect it is necessary to state the measuring distance and the measured temperature. Additionally, when relevant the ambient temperature and the temperature of the surrounding of the source (the temperature of the source aperture) when it is different from the ambient temperature has to be stated.

4.1.1.7.3 Examples of data

Size-of-source effect:

SSE: 4,5 % increase in radiance reading when increasing the radiating area from the specified (nominal) field-of-view to twice the field-of-view (doubling the area of the nominal *target area), measuring distance: 400 mm, measured temperature 500 °C, ambient temperature 23 °C*

or

SSE: 1,045 radiance ratio when increasing the radiating area from the specified (nominal) field-of-view to twice the field-of-view, measuring distance: 400 mm, measured temperature: 500 °C, ambient temperature: 23 °C

or

1,7 °C at 100 °C, 6 °C at 400 °C, 12 °C at 700 °C increase in temperature reading when increasing the radiating area from the specified (nominal) field-of-view to twice the field-of-view, measuring distance: 400 mm, ambient temperature 23 °C

4.1.1.8 Emissivity setting

4.1.1.8.1 General

For all metrological data the emissivity setting shall be 1 if not specified otherwise (see 4.1.1).

4.1.1.8.2 Required parameters

The range and the resolution of the emissivity setting shall be given. For information on the internal emissivity correction procedure the manufacturer has to be contacted.

4.1.1.8.3 Examples of data

Emissivity setting:

0,100 to 1,000, resolution 0,001

or

0,10 to 1,00, resolution 0,01

4.1.1.9 Spectral range

4.1.1.9.1 General

The spectral range is given in µm or nm. The lower and upper wavelength limits at which the spectral responsivity has reached 50 % of the peak responsivity are given as the spectral range. Alternatively, a mean wavelength and full wavelength width at which the responsivity has reached 50 % of the peak sensitivity (FWHM) are given.

NOTE For some radiation thermometers, especially for narrow band or spectral radiation thermometers, it is more useful to give lower and upper wavelength limits at which the spectral responsivity has reached significantly less than 50 % of the peak responsivity (e.g. 10 %). In this case the criteria for the wavelength limits have to be stated.

It is common for spectral radiation thermometers to give the mean wavelength of the spectral range and the FWHM, and for band pass radiation thermometers to give the lower and upper limits.

All elements of the optical system of the thermometer are to be taken into account when determining the spectral responsivity.

4.1.1.9.2 Examples of data

Spectral range:

0,9 µm, FWHM 0,2 µm

or

8 µm to 14 µm

4.1.1.10 Influence of the internal instrument or ambient temperature (temperature parameter)

4.1.1.10.1 General

The technical data of a radiation thermometer, e.g. the measurement uncertainty (3.1.2), shall be valid over the complete operating instrument or ambient temperature range and air humidity range (3.1.19), if not stated otherwise. If the measurement uncertainty is not valid in the complete operating instrument or ambient temperature range, the manufacturer shall state a temperature parameter which gives the additional measurement uncertainty when the instrument or ambient temperature deviates from a given reference temperature.

The instrument temperature is the internal temperature of the instrument. For instruments with no internal temperature indication the ambient temperature shall be stated instead of the instrument temperature. The instrument temperature value (reference temperature) or instrument temperature range for which the technical data are valid shall be stated (operating temperature range (3.1.19)). Alternatively, the ambient temperature shall be used as the reference temperature.

A deviation of the instrument or ambient temperature from the instrument reference temperature value or operating temperature range for which the technical data is valid leads to an additional measurement uncertainty. The temperature parameter gives the additional uncertainty of the measured value depending on the deviation of the temperature of the radiation thermometer from the value for which the technical data is valid after warm-up time and under stable ambient conditions. It is given as the absolute or relative increase in the uncertainty of the measured value when the instrument or ambient temperature deviates from the reference temperature.

4.1.1.10.2 Required parameters

For many instruments the temperature parameter will depend on the target temperature. In this case the temperature range for which the parameter applies has to be stated.

4.1.1.10.3 Examples of data

Temperature parameter:

0,2 °C/°C (25 °C, 600 °C), 0,02 °C/°C (25 °C > 700 °C)

additional uncertainty of the measured temperature where the internal temperature of the radiation thermometer deviates from 25 °C for a target temperature of 600 °C and for target temperatures above 700 °C

or

0,2 % of the measured value in °C/°C (23 °C)

additional relative uncertainty of the measured value where the internal temperature of the radiation thermometer deviates from 23 °C for the complete measuring temperature range

4.1.1.11 Influence of air humidity (humidity parameter)

4.1.1.11.1 General

The technical data of a radiation thermometer, e.g. the measurement uncertainty (3.1.2), shall be valid over the specified measuring distance (3.1.4) and operating temperature range and air humidity range (3.1.19), if not stated otherwise. If within the specified measurement distance the measurement uncertainty is not valid in the complete operating air humidity range, the manufacturer shall state a humidity parameter which gives the additional measurement uncertainty when the air humidity deviates from a given reference humidity.

NOTE The humidity parameter depends on a variety of factors. Its measurement by the manufacturer and its application by the user is difficult. In general, therefore, working with a humidity parameter should be avoided and the specified measurement uncertainty should be valid over the complete specified operating air humidity and measuring distance range.

The effect of humidity should be described in the operating instructions of the radiation thermometer. Some radiation thermometers allow an internal correction of the influence of humidity on the signal, when the air humidity, air temperature and measuring distance are set by the user.

The reference air humidity is the air humidity for which the technical data are valid and shall be stated.

A deviation of the air humidity from the reference air humidity leads to an additional uncertainty in temperature measurement. The humidity parameter gives the additional uncertainty of the measured temperature value depending on the relative air humidity at a defined ambient temperature. It is given as the absolute or relative increase in uncertainty in the measured value per percentage change in the air humidity relative to the reference humidity.

4.1.1.11.2 Required parameters

The humidity parameter depends on the measuring distance and when stated as a temperature shift also on the target temperature. The humidity parameter should always be stated for a measuring distance, target temperature, reference humidity and ambient temperature which is typical for the application of the radiation thermometer. If no target temperature is stated, the parameter shall be valid for the whole measuring temperature range.

4.1.1.11.3 Examples of data

Humidity parameter:

> *0,2 °C/% (50 %, 23 °C, 1 m, 600 °C), 0,1 °C/% (50 %, 23 °C, 1 m, < 500 °C)*
>
> *additional uncertainty of the measured temperature where the relative humidity deviates from 50 % at 23 °C for a measuring distance of 1 m for a target temperature of 600 °C and target temperatures below 500 °C*

or

> *0,02 % of the measured value in °C/% (45 %, 23 °C, 1 m)*
>
> *additional uncertainty of the measured value where the relative humidity deviates from 45 % at 23 °C for a measuring distance of 1 m for the complete measuring temperature range*

4.1.1.12 Long-term stability

4.1.1.12.1 General

The long-term stability should be stated in °C over a time span of 90 days or over 1 year.

4.1.1.12.2 Required parameters

The long-term stability depends on the stability of the mechanical, electrical and optical components of the radiation thermometer, the measured temperature and the confidence level. The last two parameters are to be stated.

4.1.1.12.3 Example of data

Long-term stability:

± 2 °C over 90 days

at a measured temperature of 100 °C and a confidence level of approximately 95 %

or

± 3 °C over 1 year

at a measured temperature of 100 °C and a confidence level of approximately 95 %

4.1.1.13 Short-term stability

4.1.1.13.1 General

The short-term stability should be stated in a rate °C/h or as a maximum temperature deviation within a short time span (several hours) after warm-up time.

4.1.1.13.2 Required parameters

The short-term stability depends on the measured temperature, the confidence level, the response time (3.1.16) and the internal instrument or ambient temperature. These parameters are to be stated.

4.1.1.13.3 Example of data

Short-term stability:

± 0,1 °C/h

at a measured temperature of 50 °C, a confidence level of approximately 95 %, a response time of $t_{R90\%}$ *= 1 s and an instrument temperature of 25 °C after warm-up time*

or

better than 0,5 °C at a measured temperature of 50 °C, a response time of $t_{R90\%}$ *= 1 s and an instrument temperature of 25 °C within 5 h after warm-up time*

4.1.1.14 Repeatability

4.1.1.14.1 Required parameters

The repeatability depends on the measured temperature and the response time (3.1.16) and may depend on the internal instrument or ambient temperature. These parameters are to be stated.

4.1.1.14.2 Example of data

Repeatability:

± 0,05 °C

at a response time of $t_{R90\%}$ *= 1 s, a measured temperature of 50 °C, a confidence level of approximately 95 % and an instrument temperature of 23 °C*

4.1.1.15 Interchangeability

4.1.1.15.1 General

No two instruments will differ by more than twice this figure (see example given in 4.1.1.15.2)

NOTE The interchangeability value will not necessarily be the same as the uncertainty value. It is a critical parameter for the production control, when an instrument should be replaced by another of the same type.

4.1.1.15.2 Example of data

Interchangeability:

± 2 °C in the temperature range 400 °C to 1 300 °C

4.1.1.16 Response time

4.1.1.16.1 General

The lower/upper temperature value for specifying the response time has to be a temperature value within, respectively, the lower/upper quartile of the measuring temperature range (see Figure 1).

For a radiation thermometer the rise and fall times (response times for rising and falling temperature steps) may be different. If this is the case, it shall be stated.

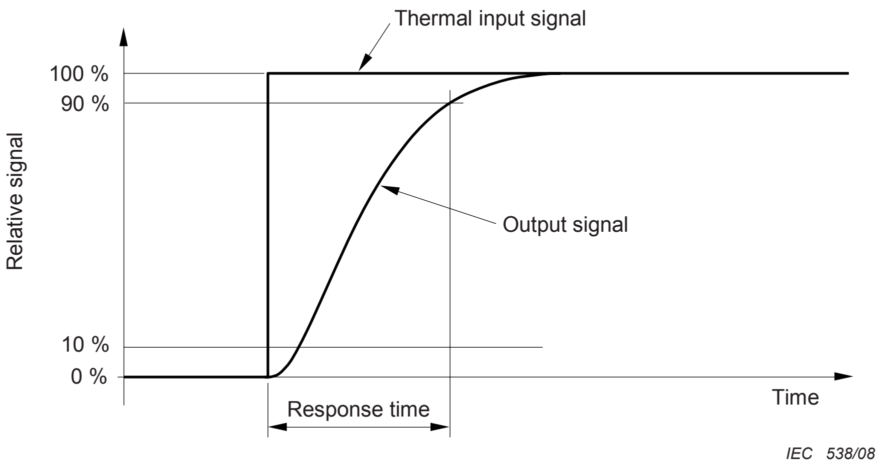

Figure 1 – Demonstration of the response time to a rising temperature step

4.1.1.16.2 Required parameters

The response time depends on the type of signal processing within the radiation thermometer. The magnitude of the temperature step (lower value and upper value) as well as the percentage or temperature limit are to be given when stating the response time. The response time has to be measured after warm up time and under stable ambient conditions.

4.1.1.16.3 Examples of data

Response time:

$t_{R90\%}$ *= 0,05 s (25 °C, 100 °C)*

0,05 s for 90 % of the maximum value of the temperature step from 25 °C to 100 °C

or

$t_{R99\%}$ *= 1 s (20 °C, 1 000 °C)*

1 s for 99 % of the maximum value of the temperature step from 20 °C to 1 000 °C

4.1.1.17 Exposure time

4.1.1.17.1 General

The exposure time is a relevant specification for radiation thermometers which have a significant delay time as part of their response time and observe objects passing through their field of view within a time span shorter than the response time (see Figure 2). In this case the exposure time is a relevant specification which shall be given by the manufacturer of the radiation thermometer.

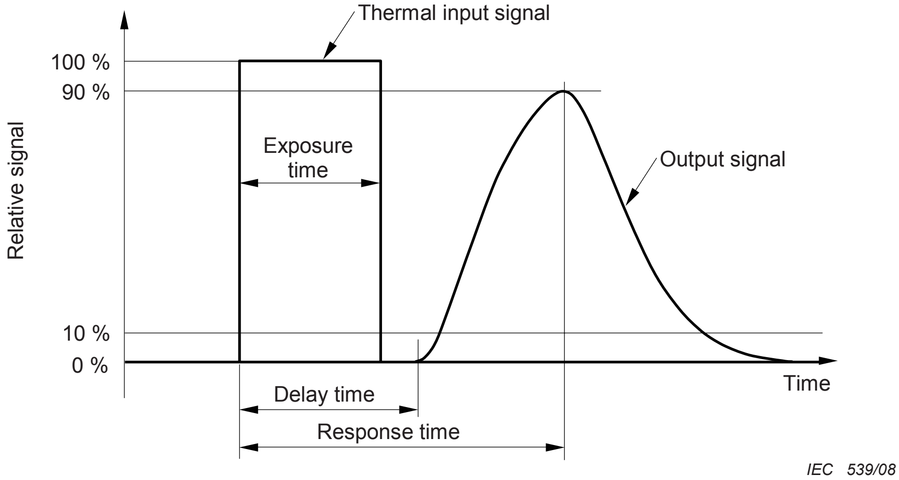

Figure 2 – Demonstration of the exposure time

4.1.1.17.2 Required parameters

The exposure time depends on the signal processing conditions within the radiation thermometer, the magnitude of the temperature step (starting value and plateau value) as well as the reached percentage of the temperature step of the output signal. The exposure time has to be measured after warm up time and under stable ambient conditions.

4.1.1.17.3 Examples of data

Exposure time:

$t_{E90\%}$ *= 0,03 s (25 °C, 100 °C, 90 %)*

0,03 s for 90 % of the maximum value of the temperature step from 25 °C to 100 °C

or

$t_{E95\%}$ *= 0,1 s (20 °C, 1 000 °C, 95 %)*

0,1 s for 95 % of the maximum value of the temperature step from 20 °C to 1 000 °C

4.1.1.18 Warm-up time

4.1.1.18.1 Example of data

Warm-up time:

15 min at 23 °C ambient temperature

4.1.1.19 Operating temperature range and air humidity range

4.1.1.19.1 General

For instruments with no internal temperature indication the ambient temperature shall be stated instead of the instrument temperature (3.1.10). The specified relative air humidity range is valid over the complete specified operating temperature range, if not stated otherwise (see 3.1.10 and 3.1.11).

4.1.1.19.2 Examples of data

Operating temperature range and air humidity range:

10 °C to 50 °C, 30 % to 70 %

or

-20 °C to 80 °C, 40 % to 60 %

or

10 °C to 50 °C, less than 85 % relative humidity at 35 °C

4.1.1.20 Storage and transport temperature range and air humidity range

4.1.1.20.1 General

The specified relative air humidity range is valid over the complete specified storage temperature range, if not stated otherwise.

Condensation is a major cause of damage to instruments in “storage”, often resulting when a cold instrument is brought into a warm environment.

4.1.1.20.2 Example of data

Storage and transport temperature range and air humidity range:

-20 °C to 80 °C, 10 % to 90 % non-condensing

4.1.2 Equipment features

Equipment features are usually application and user-orientated and should be given in addition to the metrological data.

The following are examples of equipment features:

– *type of radiation thermometer:* total radiation, broad-band, narrow-band, spectral, etc.
– *mechanical and electrical connecting conditions:* type of protection, vibration resistance, load resistance of signal converter/processor, insulation resistance, dielectric withstand voltage, etc.
– *detector:* thermopile, pyroelectric, Si, Ge, InGaAs, PbS, InSb, HgCdTe (MCT), etc.
– *output types:* display, analogue (e.g. DC 4-20 mA), digital (e.g. RS232C), etc.
– *output signal:* minimal signal step size, refresh time, etc.
– *display:* resolution, etc.
– *optical system:* aperture, lens, mirror, fibre, etc.
– *focussing:* fixed focus, variable focus
– *target marking:* yes/no, if yes type (laser, LED, …) and alignment uncertainty
– *view finder:* yes/no, if yes type and alignment uncertainty
– *component:* separate, united
– *usage:* portable, installed, etc.

Annex A
(informative)

Table A.1 hereunder gives an example of the change in indicated temperature corresponding to a 1 % change in the radiation exchange with a radiation thermometer at 23 °C.

Table A.1 – Change in indicated temperature corresponding to a 1 % change in the radiation exchange with a radiation thermometer at 23 °C

Wavelength µm	**0,65**	**0,85**	**1,0**	**1,6**	**2,2**	**3,43**	**3,9**	**5,2**	**8,0**	**11,5**
Measured Temperature °C	**Temperature Change °C**									
-100										
-50										0,7
0									0,0	0,0
50						0,2	0,2	0,2	0,4	0,4
100					0,2	0,3	0,4	0,5	0,6	0,8
150					0,3	0,4	0,5	0,6	0,9	1,1
200					0,3	0,5	0,6	0,8	1,1	1,4
250				0,3	0,4	0,7	0,7	1,0	1,4	1,8
300				0,4	0,5	0,8	0,9	1,2	1,7	2,1
350				0,4	0,6	0,9	1,1	1,4	2,0	2,5
400				0,5	0,7	1,1	1,2	1,6	2,3	2,9
450			0,4	0,6	0,8	1,2	1,4	1,9	2,6	3,3
500			0,4	0,7	0,9	1,4	1,6	2,1	3,0	3,7
550			0,5	0,8	1,0	1,6	1,8	2,4	3,3	4,1
600		0,5	0,5	0,9	1,2	1,8	2,0	2,6	3,7	4,5
650		0,5	0,6	1,0	1,3	2,0	2,3	2,9	4,0	4,9
700		0,6	0,7	1,1	1,5	2,2	2,5	3,2	4,4	5,3
750	0,5	0,6	0,7	1,2	1,6	2,5	2,8	3,5	4,8	5,8
800	0,5	0,7	0,8	1,3	1,8	2,7	3,0	3,9	5,2	6,2
850	0,6	0,7	0,9	1,4	1,9	2,9	3,3	4,2	5,6	6,6
900	0,6	0,8	1,0	1,5	2,1	3,2	3,6	4,5	6,0	7,1
950	0,7	0,9	1,0	1,7	2,3	3,5	3,9	4,9	6,4	7,5
1000	0,7	1,0	1,1	1,8	2,5	3,7	4,2	5,2	6,8	8,0
1100	0,9	1,1	1,3	2,1	2,9	4,3	4,8	5,9	7,6	8,9
1200	1,0	1,3	1,5	2,4	3,3	4,9	5,4	6,7	8,5	9,8
1300	1,1	1,5	1,7	2,8	3,7	5,5	6,1	7,4	9,4	10,7
1400	1,3	1,7	2,0	3,1	4,2	6,1	6,8	8,2	10,2	11,7
1500	1,4	1,9	2,2	3,5	4,7	6,8	7,5	9,0	11,1	12,6
1600	1,6	2,1	2,4	3,9	5,2	7,5	8,2	9,8	12,0	13,5
1700	1,8	2,3	2,7	4,3	5,8	8,2	8,9	10,6	12,9	14,5
1800	1,9	2,5	3,0	4,7	6,3	8,9	9,7	11,5	13,8	15,4
1900	2,1	2,8	3,3	5,2	6,9	9,6	10,5	12,3	14,8	16,4
2000	2,3	3,1	3,6	5,7	7,5	10,4	11,3	13,2	15,7	17,4

NOTE For "Measured Temperature" lower than marked by the bold line, the temperature of the radiation thermometer (23 °C) has to be taken in account.

The change in indicated temperature corresponding to a change in the radiant power received by the radiation thermometer is calculated as:

$$\Delta T = |T(\lambda,|(1 + B) \times (L_{(\lambda,Ts)} - L_{(\lambda,TRef)}) + L_{(\lambda,TRef)}|) - T_S|$$

where

$T\ (\lambda, L)$	is the temperature according to the inverse function of Planck's law;
$L_{(\lambda,T)}$	is the spectral radiance according to Planck's law;
λ	is the wavelength;
T_S	is the temperature of the source;
T_{Ref}	is the temperature of the reference (temperature of the radiation thermometer);
T_{Ref}	is 23 °C;
B	is 1 %.

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