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TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

Industrial process control devices – Radiation thermometers –
Part 1: Technical data for radiation thermometers

Dispositifs de commande des processus industriels – Pyromètres –
Partie 1: Données techniques pour les pyromètres

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RADIATION THERMOMETERS –

Part 1: Technical data for radiation thermometers

FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 62492-1, which is a technical specification, has been prepared by subcommittee 65B: Devices and process analysis, of IEC technical committee 65: Industrial-process measurement, control and automation.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
65B/622/DTS	65B/649/CC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This Technical Specification is one of a series of publications on radiation thermometers. Future parts of this series are planned with the following titles:

Part 2: Determination of the technical data for radiation thermometers (under consideration);

Part 3: Calibration of radiation thermometers (under consideration).

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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