INTERNATIONAL STANDARD

IEC 60216-4-1

Fourth edition
2006-01

Electrical insulating materials – Thermal endurance properties –

Part 4-1: Ageing ovens – Single-chamber ovens



Reference number
IEC 60216-4-1:2006(E)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL INSULATING MATERIALS – THERMAL ENDURANCE PROPERTIES –

Part 4-1: Ageing ovens – Single-chamber ovens

FOREWORD

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International Standard IEC 60216-4-1 was prepared by subcommittee 15E: Methods of test, of IEC technical committee 15: Insulating materials, which has now been merged with IEC technical committee 98: Electrical insulation systems into IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems (provisional title).

This fourth edition of IEC 60216-4-1 cancels and replaces the third edition, published in 1990, and constitutes a technical revision.

The main changes with regard to the previous edition is that this edition adapts IEC 60216-4-1 to the technical content and the editorial form of IEC 60216-4-2 and IEC 60216-4-3. In addition, errors and omissions in the third edition have been corrected.

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The text of this standard is based on the following documents:

FDIS	Report on voting
112/16/FDIS	112/23/RVD

Full information on the voting for the approval of this standard 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.

IEC 60216, under the general title *Electrical insulating materials – Thermal endurance properties*, is composed of several parts:

Part 1: Ageing procedures and evaluation of test results

Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria[1]

Part 3: Instructions for calculating thermal endurance characteristics

Part 4-1: Ageing ovens – Single-chamber ovens

Part 4-2: Ageing ovens – Precision ovens for use up to 300 °C

Part 4-3: Ageing ovens – Multi-chamber ovens

Part 5: Determination of relative thermal endurance index (RTE) of an insulating material

Part 6: Determination of thermal endurance indices (TI and RTE) of an insulating material using the fixed time frame method

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

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

[1] For revisions and new parts, see the current catalogue of IEC publications for an up-to-date list.

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ELECTRICAL INSULATING MATERIALS – THERMAL ENDURANCE PROPERTIES –

Part 4-1: Ageing ovens – Single-chamber ovens

1 Scope

This part of IEC 60216 covers minimum requirements for ventilated and electrically heated single-chamber ovens, with or without forced gas circulation, for thermal endurance evaluation of electrical insulation. It covers ovens designed to operate over all or part of the temperature range from 20 °C above ambient to 500 °C. It gives acceptance tests and in-service monitoring tests for these ageing ovens.

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.

ISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories*

IEC 60335 (all parts), *Household and similar electrical appliances – Safety*

3 Terms and definitions

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

3.1
rate of ventilation
N
number of air changes per hour in the exposure chamber at room temperature

3.2
exposure volume
that central part of the exposure chamber that meets the requirements for temperature fluctuation, temperature difference and temperature variation

3.3
exposure temperature
T
temperature selected for ageing test specimens to obtain data for the determination of effects of temperature

NOTE See also “global exposure temperature”.

3.4
temperature fluctuation
δT_1
maximum change in temperature at one point in the exposure volume over a period of time

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3.5
temperature difference
δT_2
maximum difference of temperature between any two points in the exposure volume at any one time

3.6
temperature variation
δT_v
difference between the highest temperature and the lowest temperature measured in the exposure volume over a period of time

3.7
global average temperature
average temperature, calculated from the results of determinations made over a period of at least 3 h using nine sensors spaced throughout the exposure volume of the chamber

3.8
global exposure temperature
considered to be equal to the global average temperature if the sensors are mounted in the same space as that containing the specimens

NOTE The term 'global exposure temperature' is frequently abbreviated to 'exposure temperature'.

3.9
time constant (of a standard specimen)
measure of time taken for the temperature of a standard specimen to approach the exposure volume temperature

3.10
temperature deviation
δT_d
calculated difference in the exposure temperature from the intended value due to the combination of the temperature difference, temperature fluctuation and the error in the measurement of temperature

NOTE Examples for calculation of temperature deviation are given in Annex B.

3.11
ventilation
continuous passage of pre-heated gas through the exposure chamber

3.12
standard oven
oven which meets the requirements of this standard

3.13
precision oven
oven with an electrically heated and ventilated chamber and with the ability to maintain the exposure temperature in its exposure volume within the limits given in IEC 60216-4-2

NOTE The limits for temperature difference and temperature fluctuation in the exposure volume given in this standard are looser than those given in IEC 60216-4-2.

3.14
oven chamber
interior volume of a single chamber oven providing the space for exposing test specimens or accommodating an iso-box (see 3.15)

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3.15
iso box
metal box with a close fitting door, mounted in the oven chamber and used as an exposure chamber to reduce the temperature deviation present in the un-modified oven chamber (see IEC 60216-4-2)

4 Constructional requirements

4.1 General

The oven shall be soundly constructed of suitable materials designed for continuous operation over the whole of the allowable temperature range.

All electrical and other ancillary fittings shall be readily accessible for maintenance purposes.

NOTE This standard does not cover all safety aspects. Additional information may be found in the IEC 60335 series.

4.2 Mechanical requirements

The materials of construction of the oven chamber and the interior fittings shall be chosen as to not influence the properties of the specimens.

NOTE Aluminium alloys and stainless steel have been found suitable in many cases. Copper based alloys and any materials that may give off interfering volatiles over the temperature range of the oven, for example some silicone resins, must not be used.

The interior of the oven shall be constructed of suitable corrosion-resistant, non-absorbent material, so fabricated that any joints are leak-proof and not subject to corrosion. The interior surfaces shall be easy to clean.

Attention shall be given to ensure that the door to the oven chamber is provided with an efficient seal and that any gasket materials used do not influence the properties of the specimens.

4.3 Ventilation

The oven chamber shall be provided with a supply of pre-heated ventilating gas, passing the chamber at one side and being exhausted through another. Wherever possible, the ventilating gas shall be directed in such a manner as to produce mixing of the ventilated gas throughout the chamber.

The rate of ventilation available shall be in accordance with 5.5

Consideration shall be given to ensure adequate purity of the incoming ventilating gas to minimize influence on the results.

If specified, inlet vents shall enable air and/or other gases to be supplied from controlled sources.

The construction shall be fitted with equipment to switch off the oven and preferably activate an alarm when the supply of ventilating gas fails.

NOTE It is recommended that the exhaust from the oven chamber be vented to outside atmosphere, but precautions should be taken to ensure that volatiles produced by ageing specimens do not damage health or the environment.

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4.4 Specimen mounting arrangements

Provision shall be made for supporting/suspending and positioning specimens within the exposure volume. The specimens shall neither touch each other nor touch the chamber walls. The specimens and supports shall not occupy more than 25 % of the cross-sectional area of the chamber in any one plane, nor occupy more than 10 % of the effective working volume of the chamber.

NOTE If there is an expectation in practice that any of these maxima could be exceeded, the supplier and purchaser should agree with the user on whether dummy loads should be used during the assessment of performance.

4.5 Temperature control and indicator systems

The temperature in the exposure volume shall be controllable to the limits given in Clause 5.

The oven chamber shall be fitted with a minimum of two temperature sensors (numbered 1 and 2). Before installation, the sensors 1 and 2 shall be calibrated by reference to a suitable standard (sensor 3) to give a maximum measurement uncertainty within ±1,0 K. The difference in reading between the two sensors as a function of temperature shall be recorded.

Sensor 3 shall have a maximum uncertainty of ±0,5 K.

Temperature sensor 1 shall be mounted in a convenient manner, and used to indicate the chamber temperature.

NOTE 1 It is recommended that the temperature should be recorded during the whole test procedure. The readout also allows early identification of any malfunction in the system.

Temperature sensor 2 shall be mounted as closely as possible to where the test specimens will be located. Its placement shall be well defined and reproducible. It may be removed after the measurements.

An independent sensor may be used to control the temperature. The placing of that sensor shall be at the manufacturer's discretion. The control system shall have a drift rate of less than 2 K/year.

NOTE 2 The sensors may be of any type that meets the requirements (for example liquid-filled thermometer, resistance thermometer).

NOTE 3 Since the performance of thermocouples is less precise than filled thermometers and resistance systems, their use is not recommended for the measurement of temperature, although they may be found suitable for the measurement of temperature difference.

Where liquid-filled thermometers are used, care shall be taken to ensure that the immersion depth in use is the same as that used during calibration.

The oven shall be equipped with an excess temperature control device which shall be independent of the main temperature control system. It shall switch off the electrical heaters in the case where the actual temperature exceeds the intended temperature by a certain pre-set amount. The system shall also ensure that a warning light or other warning device is switched on if the excess temperature device operates, and that the heaters are not started automatically again when the oven temperature has dropped below the set temperature value, but require a manual start after the warning light has been manually switched off.

5 Performance requirements

5.1 Temperature

It shall be possible to control the temperature of the exposure volume to within the limits of temperature variation over the full range claimed by the manufacturer.

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5.2 Temperature difference and temperature fluctuation

The maximum allowable temperature differences and temperature fluctuations over a period of 3 h shall be as shown in Table 1.

Table 1 – Maximum allowable temperature differences and temperature fluctuations

Temperature range °C	Maximum allowable temperature difference and fluctuation K
≤80	2
>80 to ≤180	2,5
>180 to ≤300	3
>300 to ≤400	4
>400 to ≤500	5

5.3 Temperature variation

The maximum allowable temperature variation is given in Table 2.

Table 2 – Maximum allowable temperature variation

Temperature range °C	Temperature variation K
≤80	4
>80 to ≤180	5
>180 to ≤300	6
>300 to ≤400	8
>400 to ≤500	10

5.4 Maximum temperature deviation

Within the exposure volume, the relevant temperature deviation shall not exceed 1,25 times the maximum allowable temperature variation within the relevant temperature range.

5.5 Rate of ventilation

Rates in the range 5 to 20 changes per hour shall be made available through the exposure chamber.

5.6 Exposure volume

The exposure volume shall be sufficient to accommodate the test specimens according to 4.3. It shall not be less than 50 % of the volume of the oven chamber.

NOTE Experience has shown that an exposure volume of 35 l to 70 l (litres) is generally convenient.

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5.7 Time constant

When specified in the purchase contract the time constant shall not exceed a specified value which shall be agreed between supplier, purchaser and user.

NOTE This parameter is only of importance when the oven is used for short term thermal conditioning (thermal shock testing).

6 Test methods and procedure

6.1 General

During all measurements of performance, the ambient temperature and the supply voltages to the oven shall be controlled to within the range stipulated by the manufacturer for the correct performance of the oven.

6.2 Exposure volume

The size and shape of the exposure volume are determined from the results of a series of experimental determinations of temperature difference and temperature variation, made using different placements of a series of temperature sensors at rates of ventilation to be agreed between supplier and purchase.

NOTE These temperatures might be the minimum and maximum temperatures at which the oven is designed to operate, and one approximately mid-way between these two, for example 50 °C, 250 °C and 500 °C.

6.3 Temperature and related parameters

6.3.1 Practical aspects

The temperature of the oven chamber and, finally, of the exposure volume shall be determined using temperature sensor number 2 (see 4.5).

For the determination of temperature difference and temperature fluctuation, place a series of temperature sensors (maximum time constant 30 s) in the oven chamber under investigation, ensuring that:

– one sensor is located within 25 mm of the centre of the chamber;

– one additional sensor is located (50 ± 10) mm distance from the walls in each of the eight corners of the chamber.

The length of wire connecting the temperature sensors to the indicating system shall be chosen such that the indicated temperature is not influenced by thermal conduction from the oven. Externally the wires shall be thermally insulated and maintained in essentially draught-free conditions.

NOTE 1 In order to evaluate temperature difference and temperature fluctuation, if calibrated temperature sensors are not available, thermocouples made from the same spool of thermocouple wire and prepared in the same manner may be used provided that, when placed adjacent to one another in the testing chamber at the maximum operating temperature, they give values of temperature that do not differ by more than 0,4 K. A similar procedure may be used with other uncalibrated temperature sensors.

Set the level of ventilation at the manufacturer's stated minimum.

Allow the temperature of the chamber to stabilize.

Measure and record the temperature of the individual sensors to 0,1 K a sufficient number of times over a period of approximately 3 h to allow identification of any cyclic behaviour and permit determination of the maximum, minimum and mean temperatures of each temperature sensor over the measuring period.

NOTE 2 Continuous monitoring of the temperatures is recommended.

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6.3.2 Calculations

Temperature fluctuation (δT_1)

Inspect the data and calculate the maximum difference in temperature, recorded over a period of 3 h, for each of the nine sensors. Identify the largest of these differences, and record that as the "day 1 temperature fluctuation".

Temperature difference (δT_2)

Inspect the data and calculate the maximum temperature difference present in the exposure chamber at any one time during the period of 3 h. Record that as the "day 1 temperature difference".

6.3.3 Results

If the results meet the requirements for temperature variation, repeat the measurements every day for a period of five days.

Repeat the calculations for the remainder of the data and record the day 2, 3, 4 and 5 temperature differences. Select the largest of these day temperature differences and record as the (oven) temperature variation δT_1.

If the measured oven temperature variations fall within the requirements, the oven shall be said to conform with the requirements at the particular chamber temperature and ventilation level. The exposure volume is the space within the eight corner sensors (see 5.1).

If the results do not meet the requirements, reposition the sensors at least 25 mm further from the walls and repeat the tests and calculations (see 5.1).

If the measured oven temperature variation falls within the requirements, the oven shall be said to conform with the requirements at the particular chamber temperature and ventilation level. The exposure volume is the space within the eight repositioned corner sensors (see 5.1).

Repeat the measurements at the other two chamber temperatures using appropriate ventilation rates to determine the exposure volume for these temperatures.

The temperature deviation δT_d can be calculated in accordance with Annex B, using the calculated value of temperature difference, the difference between the readings of the temperature sensors 1 and 2 as determined from the initial calibration, and by reference to the exposure temperature as indicated by the readout from sensor 1 during long-term heat ageing experiments.

6.4 Rate of ventilation

Any adequate method may be used to determine the rate of ventilation if a metered supply is not used.

One procedure which is based on the measurement of the increase in power consumption required to maintain the temperature in the oven chamber with the vents open, over that required to maintain the exposure chamber at the same temperature with the vents closed is given in Annex A.

The gas supply and exhaust system shall be adjusted until the measured rate of ventilation meets the requirements.

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6.5 Time constant

Provide a standard specimen consisting of a solid brass cylinder (10 ± 0,1) mm in diameter and (55 ± 0,1) mm long to which one junction of a differential thermocouple has been soldered.

Raise the oven temperature to 200 °C or its maximum designed temperature, whichever is the lower, and allow it to stabilize. Allow the standard specimen to stabilize at ambient temperature for at least 1 h.

Following the manufacturer's instructions, open the chamber and quickly hang the standard specimen with its axis vertical and close to the geometric centre of the oven by the use of a heat resistant cord not larger than 0,25 mm diameter. Ensure that the second junction of the thermocouple assembly is suspended as far away as possible from the standard specimen without touching the walls of the chamber and within the exposure volume. Leave the chamber open for a total time of (60 ± 2) s and then close the door of the chamber. Record the temperature difference every 10 s until the maximum has been established. Continue recording every 30 s until the temperature difference has dropped below 10 % of the maximum, and plot the values recorded against time in seconds.

Divide the maximum temperature difference by ten and record as T_{10}. Record as the time constant the time in seconds, taken from the plot of temperature difference versus time, for the temperature difference to pass through a maximum and decrease to T_{10}.

7 Report

The report shall comply with the requirements given in ISO/IEC 17025 wherever possible. The supplier of the oven shall include in the test report at least the following information:

a) A title (e.g. “Test report” or “Calibration certificate” according to IEC 60216-4-1).

b) The name and address of the oven manufacturer.

c) The name and address of the test laboratory, and the location where the tests and/or calibrations were carried out.

d) Unique identification of the test report or calibration certificate (such as a serial number), and on each page an identification in order to ensure that the page is recognized as a part of the test report or calibration certificate, and a clear identification of the end of the test report or calibration certificate.

e) The name and address of the client.

f) A description, the condition of, and an unambiguous identification of the item(s) tested or calibrated.

g) Type and designation:
   - range of supply voltage over which the oven conforms with this standard;
   - maximum power consumption;
   - range of ambient temperature over which the oven conforms with this standard;
   - mass of the complete (empty) oven and external dimensions;
   - definition of the exposure volume versus temperature over which the requirements for temperature difference, temperature fluctuation and temperature variation conform with this standard;
   - range of available ventilation rates;
   - results of the tests described in Clause 6.
   - recommendations on methods of controlling the quality of the ventilating gas, e.g. filtration, dehumidification and appropriate methods of measurement;
   - when required, report the time constant.

h) The name(s), function(s) and signature(s) or equivalent identification of the person(s) authorizing the test report or calibration certificate.

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i) Where relevant, a statement to the effect that the results relate only to the items tested or calibrated.

8 Conditions of use and instructions for in-service monitoring by the user

8.1 Conditions of use

a) During use, the ambient temperature and the supply voltages shall be controlled within the range stipulated by the manufacturer for the correct performance of the oven.

b) Unless otherwise specified, the quality of the ventilating gas shall be sufficient not to affect significantly the results. In cases where the results of tests are influenced by impurities in the ventilating medium, for example, water vapour, it shall be controlled and reported.

c) Where a number of ageing ovens are in use in a local area, care shall be taken to prevent cross-contamination of volatile components, i.e. ventilating gas from one oven shall not come into contact with specimens in any other oven.

NOTE It is recommended that the exhaust from each oven be vented directly to outside atmosphere.

d) Precautions shall be taken to ensure that volatiles produced by the ageing process do not damage health or the environment.

e) During temperature exposure, no test specimen shall be stored outside of the exposure volume, and specimens shall only touch the supports and not touch each other.

8.2 Procedure

Prior to long-term heat ageing, the temperature in the oven chamber shall be adjusted to the nominal exposure temperature as measured by temperature sensor 2 which shall be placed as close as possible to where the test specimens will be located. Its placement shall be well-defined and reproducible.

Where liquid-filled thermometers are used, care shall be taken to ensure that the immersion depth in use is the same as that used during calibration.

8.3 In-service monitoring

The following test on a loaded oven shall be made immediately before each ageing test.

NOTE 1 These tests are to confirm that the loaded oven meets the requirements of this specification at the beginning of the ageing test. In the tests, the global exposure temperature and the temperature variation are determined.

Following the general procedure given in 6.3:

a) place a series of eight temperature sensors within, but close to the periphery of the mounted specimens in the exposure volume under evaluation;

b) raise the oven temperature to the planned temperature and allow to stabilize;

c) determine the global average temperature (which is assumed to be the initial exposure temperature) and the temperature variation over a period of at least 3 h using data from the eight sensors in addition to that from sensor 2.

If the results do not meet the requirements, terminate the ageing programme and re-organize the test specimen mounting arrangements or otherwise adjust the equipment until, on repeating the tests, conformance is confirmed.

If it is desired to estimate a more precise exposure temperature than that determined in the test above, then a long-term average of the temperatures measured using sensor 2 should be calculated.

NOTE 2 It is recommended that users consider the implications of Annex B, with regard to the precision of any measured ageing data.

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Annex A
(informative)

Test method to determine the rate of ventilation

NOTE Any other method of equivalent accuracy may be used.

A.1 General requirement

During the tests, the mean ambient temperature for the procedure given in Clause A.2 shall be the same as that for Clause A.3.

A.2 Sealed oven

The oven shall be properly sealed, including vent ports, door, temperature sensor port and blower shaft or complete blower, if applicable. A watt-hour meter with accuracy of ±1 Wh or better shall be connected into the oven power supply line and the oven energized. An appropriate control temperature shall be chosen and set.

After the oven temperature has stabilized, the following measurements shall be taken:

– room temperature at a point 2 m distance from any significant thermal source, at least 1 m from any solid object and at about the same level as that of the oven inlet vent;

– electrical energy E_1 consumed over a period of time of at least 1 h to within ±2 Wh, with the corresponding time measured to within ±3 s.

A.3 Ventilated oven

After all seals being removed, the size of the damper for the inlet vent shall be estimated to give the required rate of ventilation. Again, after the oven temperature has stabilized, consumption of electrical energy E_2 shall be determined as under Clause A.1 for the same period of time.

A.4 Calculation

The rate of ventilation is calculated by the following equation:

$$N = [10(P_2 - P_1)T_a]/V_o(T - T_a)$$

where

N is the rate of ventilation;

P_1 is the mean power consumption, in watts, of the non-ventilated oven, obtained by dividing the energy consumption E_1, in watt-hours, determined from the watt-hour meter reading by the duration of the test, in hours;

P_2 is the mean power consumption, in watts, of the ventilated oven, obtained by dividing the energy consumption E_2, in watt-hours, determined from the watt-hour meter reading by the duration of the test, in hours;

V_o is the volume of the exposure chamber, in litres;

T_a is the mean ambient temperature, in kelvins;

T is the exposure temperature, in kelvins.

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NOTE The calculation is based on the following assumptions:

The density of gas at ambient temperature is

$$d_{Ta} = d_{20}T_{20}/T_a \text{ in kg/l with } T_{20} = 293 \text{ K}$$

The density d_{20} = 1,204 5 × 10^{-3} (kg/ℓ)

For calculation purposes, a mean value is used for the specific thermal capacity of gas at 180 °C, which is

$$c_p = 1{,}022 \times 1\,000 \text{ (J/kg K)}$$

The total mass of gas flow during the test period is

$$M = 3\,600\,(E_2 - E_1) / c_p(T - T_a) \text{ (kg)}$$

when the gas flow is heated from T_a to T and E_1 (see Clause A.1) and E_2 (see Clause A.2) the energy consumption in Wh derived from the Watt-hour meter readings.

The total volume of gas flow during the test period is

$$V = M / d_{Ta} = 3\,600(E_2 - E_1) / c_p(T - T_a)d_{Ta} \text{ (ℓ)}$$

The volume per hour is

$$V_h = 3\,600\,(P_2 - P_1) / c_p(T - T_a)d_{Ta} \text{ (ℓ/h)}$$

The rate of ventilation is

$$N = V_h / V_o = 3\,600(P_2 - P_1) / c_p(T - T_a)d_{Ta}V_o = 3\,600(P_2 - P_1)T_a / c_p(T - T_a)d_{20}T_{20}V_o$$

$$N = 3\,600(P_2 - P_1)T_a / 293 \times 1{,}022 \times 1{,}205(T - T_a)V_o$$

$$N \sim 10{,}0 \times (P_2 - P_1)T_a / V_o(T - T_a)$$

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Annex B
(informative)

Examples for calculation of temperature deviation

Error of measurement

The maximum error of measurement consists of the following elements:

- random error u_1 = ±0,5 K occurs two times, during calibration and reading of temperature sensor 1;
- random error u_2 = ±0,5 K occurs two times, during calibration and reading of temperature sensor 2;
- systematic error u_3 = ±0,1 K of temperature sensor 3;
- the maximum possible error occurs if all errors u_1, u_2 and u_3 act in the same direction, $\delta T_f = 2u_1 + 2u_2 + u_3$, but as this is very improbable, an estimate of the most likely maximum error is introduced as a geometric mean, i.e. the square root of the sum of the squares of the individual maximum errors. The most likely true deviation is then determined as the square root of sum of the most likely maximum error, added to the square of the maximum measured variation to get an estimate of the square of the maximum assessed deviation (maximum temperature variation δT_v equals maximum temperature fluctuation plus the maximum temperature difference in a period of 3 h.)

For example when T_f =1 *and* T_d =1 (temperature range <180 °C)

$\delta T_{Vmax} = \delta T_{fmax} + \delta T_{dmax} = 1 + 1 = 2$

With these assumptions, the temperature deviation of the exposure temperature is given by the following relation:

$$\delta T_d = \pm \sqrt{(2u_1^2 + 2u_2^2 + u_3^2 + \delta T_v^2)} \text{ K}$$

$$\delta T_d = \pm \sqrt{(1{,}01 + \delta T_v^2)} \text{ K}$$

The maximum possible temperature deviation, from the above equation, is

$$\delta T_d = \pm \sqrt{(1{,}01 + 4)} \text{ K}$$

$$\delta T_d \sim \pm 2{,}2 \text{ K}$$

For other temperature ranges the maximum temperature deviation can be calculated in a similar manner.

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