# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

**IEC**
**CEI**

# 60068-3-11

First edition
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**Environmental testing –**

**Part 3-11:**
**Supporting documentation and guidance –**
**Calculation of uncertainty of conditions**
**in climatic test chambers**



**Essais d'environnement –**



**Partie 3-11:**
**Documentation d'accompagnement et guide –**
**Calcul de l'incertitude des conditions**
**en chambres d'essais climatiques**

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## FOREWORD

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International Standard IEC 60068-3-11 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

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

| FDIS | Report on voting |
|---|---|
| 104/409/FDIS | 104/415/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.

A list of all parts in the IEC 60068 series, under the general title *Environmental testing* can be found on the IEC website.

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- withdrawn,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.

# INTRODUCTION

This part of IEC 60068 provides guidance for analysing uncertainties of temperature and humidity in climatic test chambers. It has been written for technicians, engineers and managers in environmental testing, and for anyone who needs to understand the results of environmental tests.

The performance of climatic test chambers is a key concern in environmental test engineering. To comply with any test specification, the performance of the chamber needs to be characterized to decide whether the generated conditions fall within the specified limits. This characterization can be a difficult task, and the analysis of uncertainties in chamber performance is often surrounded by confusion. This publication is intended to ease that process.

In what follows, the concept of uncertainty of measurement is introduced first and then the significance of tolerance discussed. Aspects of humidity and temperature measurement are considered, followed by methods for determining and combining uncertainties. The cases of both calibrating an empty chamber and of measuring conditions in a loaded chamber are considered. Finally, detailed guidance and worked examples are given for analysing results to give estimates of uncertainty in the measured performance.

# ENVIRONMENTAL TESTING –

## Part 3-11: Supporting documentation and guidance – Calculation of uncertainty of conditions in climatic test chambers

## 1 Scope

This part of IEC 60068 demonstrates how to estimate the uncertainty of steady-state temperature and humidity conditions in temperature and humidity chambers. Since this is inextricably linked to the methods of measurement, these are also described.

This standard is equally applicable to all environmental enclosures, including rooms or laboratories. The methods used apply both to temperature chambers and combined temperature and humidity chambers.

This standard is meant to help everyone using climatic test chambers. Those already familiar with uncertainty of measurement will find it useful for guidance on typical sources of uncertainty and how they should be quantified and combined. It is also intended to assist the first-time or occasional user who has little or no knowledge of the subject.

To discuss uncertainty, it is important first to understand what is being measured or characterized. The calibration or characterization of the performance of a chamber is concerned with the humidity and temperature of the air in the chamber, as experienced by the item under test, at a given set point. This should not be confused with characterizing or calibrating the chamber sensor, which is a separate matter.



## 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.

IEC 60068-3-5: *Environmental testing – Part 3-5: Supporting documentation and guidance – Confirmation of the performance of temperature chambers*

IEC 60068-3-6: *Environmental testing – Part 3-6: Supporting documentation and guidance – Confirmation of the performance of temperature/humidity chambers*

ISO 3534-1:2006, *Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability*

ISO 3534-2:2006, *Statistics – Vocabulary and symbols – Part 2:Applied statistics*

*International Vocabulary of basic and general standard terms in metrology.* ISO, Geneva, Switzerland 1993 (ISBN 92-67-10175-1) – VIM

*Guide to the expression of uncertainty in measurement.* ISO, Geneva, Switzerland 1993. (ISBN 92-67-10188-9) – GUM

## 3 Terms and definitions

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

**3.1**
**calibration authority**
laboratory or other organization that performs calibrations and is itself accredited by the appropriate national accreditation body

**3.2**

**climatic test chamber**
enclosure
chamber or enclosed space where the internal temperature or temperature and humidity can be controlled within specified limits

**3.3**
**combined standard uncertainty**
standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities



See also GUM.



**3.4**
**correction**
value added algebraically to the result of a measurement to compensate determinable systematic error

See also VIM.

**3.5**
**confidence level**
value of probability associated with a confidence interval

NOTE The confidence level is the likelihood that the “true value” lies within the stated range of uncertainty usually expressed as a percentage, e.g. 95 %.

See also ISO 3534-1.

**3.6**
**coverage factor**
numerical factor to multiply the combined standard uncertainty to obtain an expanded uncertainty

NOTE A coverage factor of k=2 corresponds to a confidence level of approximately 95 % if normally distributed and if the number of degrees of freedom is sufficiently large.

See also GUM.

**3.7**
**dew point**
temperature at which the partial pressure of the water vapour is equal to the saturation vapour pressure over water or ice

NOTE The temperature to which the air would have to cool (at constant pressure and constant water vapour content) in order to reach saturation. A state of saturation exists when the air is holding the maximum amount of water vapour possible at the existing temperature and pressure.

**3.8**
**dispersion**
spread of repeated measurements of a quantity

**3.9**
**drift**
change in the indication of a measuring system not related to a change in the quantity being measured

See also VIM.

NOTE The drift since the last calibration can be estimated and a correction applied to measured values.

**3.10**
**error**
difference between result of a measurement and the true value



**3.11**
**expanded uncertainty**
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand



See also VIM.

**3.12**
**fluctuation**
change (from the mean) in the temperature or humidity after stabilization from time to time at a point in space

NOTE It may be measured by standard deviation or maximum deviation.

**3.13**
**gradient**
maximum difference in mean value, after stabilization, at any moment in time between two separate points in the working space

**3.14**

**incident air**
conditioned airstream which flows into the working space

**3.15**
**partial vapour pressure**
contribution of water vapour in a given volume of air at a constant pressure and temperature of the atmosphere

**3.16**
**reference instrument**
previously calibrated instrument used to measure the conditions within the enclosure

**3.17**
**relative humidity**
ratio of actual partial vapour pressure to the saturation vapour pressure at any given temperature and pressure, expressed as a percentage (% RH)

**3.18**
**repeatability**
closeness of agreement between independent results obtained in the normal and correct operation of the same method on identical test material, in a short space of time, and under the same test conditions (such as the same operator, same apparatus, same laboratory)

**3.19**
**resolution**
smallest changes between indications of the chamber controller display that can be meaningfully distinguished

**3.20**
**saturation vapour pressure**
when a given volume of air, at a constant temperature, has water vapour present and is incapable of holding more water vapour it is said to be saturated

**3.21**
**stabilization**
achievement of the state of temperature/humidity in the chamber when all mean values in the working space are constant and have maintained temperature/humidity within a given tolerance



**3.22**
**standard deviation**
measure of the dispersion of a set of measurements

NOTE The standard deviation, s, is the best estimate of sigma (the population standard deviation).

See also GUM and/or VIM.

**3.23**
**standard uncertainty**
uncertainty of the result of a measurement expressed as a standard deviation

See also GUM.

**3.24**
**tolerance**
acceptance limit specified or chosen for a process or product

See also ISO 3534-2.

**3.25**
**traceability**
property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons, all having stated uncertainties

NOTE The unbroken chain of comparisons is called a traceability chain.

See also ISO 3534-1 and VIM.

**3.26**
**true value**
value which characterizes a quantity, perfectly defined in the conditions which exist when that quantity is considered

NOTE The true value of a quantity is a theoretical concept and, in general, cannot be known exactly but is estimated by measurement.

See also ISO 3534-1.

**3.27**
**uncertainty**
parameter, associated with the result of a measurement, which characterizes the dispersion of the values that could reasonably be attributed to it

**3.28**
**uncertainty budget**
list of sources of uncertainty compiled with a view to evaluating a combined standard uncertainty associated with a measurement result

**3.29**
**uncertainty contribution**
input to an uncertainty budget

**3.30**
**working space**
part of the chamber in which the specified conditions can be maintained within the specified tolerances



# 4 Concept of uncertainty

## 4.1 Uncertainty, error and “true value”

In every measurement – no matter how careful – there is always a margin of doubt about the result. In simple terms, the uncertainty of a measurement is a quantification of the doubt about the measurement result.

While discussing uncertainty we often also need to consider a related but separate concept, “error”. A measurement “error” is the difference between the measured value and the “true value” of the thing being measured.

The “true value” of any quantity is in principle unknowable. This leads to a problem since the “error” is defined as the result of a measurement minus the “true value”. Sometimes this difference can be estimated. Both terms are best avoided as much as possible and, when necessary, should be used with care. Discussion of “error analysis”, which used to be included in many scientific papers, should have been entitled “analysis of the probable limits of error”, or more properly, ”analysis of uncertainty”. In older publications the term “error” was widely used when ‘uncertainty’ would have been the correct term.

Uncertainty is not the same as error. If the conditions in a test chamber are measured with a calibrated instrument and the result is 75 % RH when the chamber controller says 90 % RH, that does not mean the uncertainty is 15 % RH. It is known that the relative humidity is 75 % RH. One is aware that either the controller reading is wrong or the chamber is operating incorrectly. It has an error estimated to be 15 % RH. The uncertainty is a characteristic of the measurement that gave the answer 75 % RH. Could that be wrong and, if so, by how much?

When considering “true value”, uncertainty, and error, one of the most important sources of this type of information for a measuring instrument is its calibration certificate. It is vital to use all of the information provided by the calibration certificate to ensure that the best estimate of the test uncertainties are obtained.

## 4.2 Statements of uncertainty

### 4.2.1 General

When reporting the results of a measurement, three numbers are necessary for a metrologically correct and complete statement of the result of each measurement point. For example, the complete statement could be:

The “true value” is: 39,1 °C ± 0,3 K with 95 % confidence:

- 39,1 °C is the best estimate of the true value;
- ±0,3 K is the confidence interval;
- 95 % is the confidence level.

An explanation of these three components follows.

### 4.2.2 Best estimate of the true value of the measured quantity

Often this will simply be the reading on the calibrated reference instrument which, in the case of a climatic test, could be the temperature measurement system and/or hygrometer reading, or if the chamber has been calibrated it could be the chamber controller display. If the calibration shows either for an instrument or for a chamber controller that an error exists (which is not an uncertainty), this should be used to apply a correction. For example, if the calibration of a thermometer shows that it reads 1 K high, 1 K should be subtracted from the reading to obtain the best estimate of the true value.



### 4.2.3 Confidence interval

This is the range of measured values within which the “true value” lies with a given level of confidence. In our example this interval is ±0,3 K.

### 4.2.4 Confidence level

The “confidence level” of a measurement is a number (e.g. 95 %) expressing the degree of confidence in the result. This is the probability that the real “true value” lies in the given range. Most sets of data are normally distributed and about 68 % of the values will fall within plus or minus one standard deviation of the mean. About 95 % of the values can be expected to fall within plus or minus 2 standard deviations (95 % confidence level). Put another way, when many such measurements are performed not more than 1 in 20 will lie outside the stated limits. Hence multiplying the standard deviation by 2 is an accepted way of encompassing 95 % of the range of values. With a 95 % confidence level, we are 95 % sure that the “true value” lies in the stated range.

It is conventional to work at the 95 % confidence level. Higher confidence levels can be used but the confidence interval will increase.

### 4.2.5 Statement of uncertainty

In the above example the statement of uncertainty is that the temperature was 39,1 °C± 0,3 K with 95 % confidence. 39,1 °C was the best estimate of the temperature but because of the uncertainties there is a possibility of it being in the range 38,8 °C to 39,4 °C with a confidence of 95 %.

### 4.3 Combining uncertainties

Uncertainty contributions shall be expressed in similar terms before they are combined. They shall be in the same units and at the same level of confidence. All contributions should be converted into standard uncertainties (i.e. having a confidence level of plus or minus one standard deviation). This is discussed further in Clauses 9 and 10.

## 5 Tolerance

When a test item is to be conditioned one of the first questions asked is, “Will the chamber achieve and maintain the required conditions?” This is asked since the test specification will often set a tolerance for the required condition e.g. ±2 °C and ±5 % RH. In deciding whether a tolerance is met, the uncertainty in the measured chamber performance shall be taken into account.

Tolerances are not the same as uncertainties. Tolerances are acceptance limits which are chosen for a process or product. Most often the aim of knowing the uncertainty in a chamber’s performance is to decide whether a tolerance is met. In deciding this, the deviation from the required condition, together with the uncertainty, shall be considered. Using the values cited in 4.2.5, it is certain to within 95 % that the true temperature is between 38,8 °C and 39,4 °C. If the required condition is 40 °C ± 2 K, then the probability that the true temperature lies within the tolerance is considerably better than 95 % because the entire confidence interval lies within the range of the tolerance.

If the measured humidity is 81,7 % RH, and the confidence interval is ±3,6 % RH at a 95 % confidence level, then it is certain to within 95 % that the true humidity is between 78,1 % RH and 85,3 % RH. If the required condition is 85 ± 5 % RH, even though the measured condition is within this range, the probability that the true humidity is within ±5 % RH of the set point is significantly less at a 95 % confidence level, because the entire confidence interval does not lie within the range of the tolerance. However, from the uncertainty, there are statistical methods for making a good estimate of how likely this is.



## 6 Humidity and temperature measurement

When taking humidity measurements there are many ways of approaching the situation. It is generally assumed that the water vapour content of the air is uniform throughout the chamber. This is a reasonable assumption, and people who have performed measurements of humidity at multiple points in a chamber can confirm that this is normally the case. However, this does not mean that the relative humidity is uniform.

Dew point, being directly related to vapour pressure, can be assumed to be uniform across the chamber and is not affected by temperature. It may be that during routine tests, humidity measurement is only made in one place. However, at some point, either during the test or when the chamber is operating under similar conditions, humidity measurements shall be made in at least two places so that an uncertainty can be assigned to the assumption that the vapour content of the air is uniform.

For most environmental tests, the required humidity is specified in terms of relative humidity. The importance of relative humidity arises because the behaviour of most organic materials depends on this parameter. Factors such as physical expansion of plastics and wood, biological activity, electrical impedance and corrosion rates are examples of processes that are affected by the relative humidity.

In a chamber the vapour pressure is often nearly uniform.