INTERNATIONAL STANDARD

ISO 5725-1

Second edition
2023-07

Accuracy (trueness and precision) of measurement methods and results —

Part 1: General principles and definitions

Exactitude (justesse et fidélité) des résultats et méthodes de mesure —
Partie 1: Principes généraux et définitions

Reference number
ISO 5725-1:2023(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 6, *Measurement methods and results*.

This second edition of ISO 5725-1 cancels and replaces the first edition (ISO 5725-1:1994) which has been technically revised. It also incorporates the Technical Corrigendum ISO 5725-1:1994/Cor.1:1998.

The main changes are as follows:

— normative references have been revisited;

— some definitions have been deleted (observed value, cell in a precision experiment, collaborative assessment experiment) and others have been added (repeatability critical difference, reproducibility critical difference, intermediate precision conditions, intermediate precision standard deviation, intermediate precision critical difference, intermediate precision limit);

— the number of laboratories required for a precision study and Annex B presenting charts of uncertainties for precision measures have been moved in ISO 5725-2;

— guidance on the practical use of trueness and precision to evaluate uncertainty and the use of ISO 21748 was added.

A list of all parts in the ISO 5725 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

0.1 The general term accuracy is used in ISO 5725 (all parts) to refer to both trueness and precision.

The term accuracy was at one time used to cover only the one component now named trueness, but it became clear that to many persons it should imply the total displacement of a result from a reference value, due to random as well as systematic effects.

The term bias has been in use for statistical matters for a very long time, but because it caused certain philosophical objections among members of some professions (such as medical and legal practitioners), the positive aspect has been emphasized by the invention of the term trueness.

0.2 ISO 5725 (all parts) uses two terms "trueness" and "precision" to describe the accuracy of a measurement method. "Trueness" refers to the closeness of agreement between the arithmetic mean of a large number of test results and the true or accepted reference value. "Precision" refers to the closeness of agreement between test results obtained under stipulated conditions.

0.3 The need to consider "precision" arises because tests or measures performed on presumably identical test items in presumably identical circumstances do not, in general, yield identical results. This is attributed to unavoidable random errors inherent in every measurement procedure; the factors that influence the outcome of a measurement cannot all be completely controlled. In the practical interpretation of measurement data, this variability should be taken into account. For instance, the difference between a test result and some specified value may be within the scope of unavoidable random errors, in which case a real deviation from such a specified value has not been established. Similarly, comparing test results from two batches of product will not indicate a fundamental quality difference if the difference between them can be attributed to the inherent variation in the measurement procedure.

0.4 The general term for variability between replicate measurements is precision. Two conditions of precision, termed repeatability and reproducibility conditions, have been found necessary and, for many practical cases, useful for describing the variability of a measurement method. Under repeatability conditions, all factors that influence the measurement are considered constant and do not contribute to the variability, while under reproducibility conditions, some or all influential factors vary and do contribute to the variability of the test results. Thus repeatability and reproducibility are the two extremes of precision, the first describing the minimum and the second the maximum variability in results. Other intermediate conditions between these two extreme conditions also occur when one or more of the factors that influence the measurement are allowed to vary, and are used in certain specified circumstances. Precision is normally expressed in terms of standard deviations.

0.5 The purpose of ISO 5725 (all parts) is as follows:

a) to outline the general principles to be understood when assessing accuracy (trueness and precision) of measurement methods and results, and in applications, and to establish practical estimations of the various measures by experiment (ISO 5725-1);

b) to provide basic methods for estimating the two extreme measures of the precision of measurement methods by experiment, giving the circumstances in which they apply (ISO 5725-2);

c) to provide designs for obtaining intermediate measures of precision, giving the circumstances in which they apply and methods for estimating them and to provide some alternative designs to those given in ISO 5725-2, for determining the precision and trueness of measurement methods for use under certain circumstances (ISO 5725-3);

d) to provide basic methods for the determination of the trueness of a measurement method (ISO 5725-4);

e) to provide some alternatives to the methods, given in ISO 5725-2 to ISO 5725-4, for determining the precision and trueness of measurement methods for use under certain circumstances (ISO 5725-5);

f) to present some practical applications and use of these measures of trueness and precision (ISO 5725-6).

Accuracy (trueness and precision) of measurement methods and results —

Part 1: General principles and definitions

1 Scope

1.1 This document

— introduces conditions, constraints and resources necessary to evaluate a measurement method or a result;

— defines an organizational scheme for the acquisition of trueness and precision data by study;

— provides the necessary definitions, statistical model and principles for ISO 5725 (all parts).

— is not applicable to proficiency testing or production of the reference item that has their own standards (ISO 13528, respectively and ISO Guide 35).

1.2 This document is concerned exclusively with measurement methods which yield results on a continuous scale and give a single value as the test result, although this single value may be the outcome of a calculation from a set of observations.

It defines values which describe, in quantitative terms, the ability of a measurement method to give a true result (trueness) or to replicate a given result (precision). Thus, there is an implication that exactly the identical item is being measured, in exactly the same way, and that the measurement process is under control.

This document may be applied to a very wide range of test items, including gas, liquids, powders and solid objects, manufactured or naturally occurring, provided that due consideration is given to any heterogeneity of the test item.

This document does not include methods of calculation that are described in the other parts.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 3534-1, ISO 3534-2 and the following apply.

The symbols used in ISO 5725 (all parts) are given in Annex A.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
test result
value of a characteristic obtained by carrying out a specified test method

Note 1 to entry: The test method should specify that one or a number of individual observations be made, and their average or another appropriate function (such as the median or the standard deviation) be reported as the test result. It can also require standard corrections to be applied, such as correction of gas volumes to standard temperature and pressure. Thus a test result can be a result calculated from several observed values. In the simple case, the test result is the observed value itself.

Note 2 to entry: When measurement is used (for methods or results) in this document it means test or measurement (for methods or results).

[SOURCE: ISO 3534-2:2006, 3.4.1, modified — Note 2 to entry rephrased.]

3.2
accepted reference value
value that serves as an agreed-upon reference for comparison, which is derived as:

a) a theoretical or established value, based on scientific principles;

b) an assigned or certified value, based on experimental work of some national or international organization;

c) a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group;

d) the expectation, i.e. the mean of a specified population of measurements when a), b) and c) are not available.

[SOURCE: ISO 3534-2:2006, 3.2.7]

3.3
level
<test item> general average of the *test results* (3.1) or *test results* (3.1) from all laboratories for one particular test item or test item tested

Note 1 to entry: The accuracy of a measurement method is defined at each level and can be different.

3.4
measurement
test item
sample which is prepared and can be presumed to be identical for the intended purpose

Note 1 to entry: Practical requirements are stated in the protocol of the intended purpose.

Note 2 to entry: Examples of test items: sample, product, artifact, reference test item, equipment, measurement standard.

3.5
accuracy
closeness of agreement between a *test result* (3.1) and the true value

Note 1 to entry: In practice, the accepted reference value is substituted for the true value.

Note 2 to entry: The term accuracy, when applied to a set of test results, involves a combination of random components and a common systematic error or bias component.

Note 3 to entry: Accuracy refers to a combination of trueness and precision.

Note 4 to entry: Common systematic error is called bias component.

[SOURCE: ISO 3534-2:2006, 3.3.1, modified — Note 4 to entry added.]

3.6
trueness
closeness of agreement between the expectation of *test results* (3.1) and a true value

Note 1 to entry: The measure of trueness is usually expressed in terms of bias.

Note 2 to entry: Trueness is sometimes referred to as "accuracy of the mean". This usage is not recommended.

Note 3 to entry: In practice, the accepted reference value is substituted for the true value.

[SOURCE: ISO 3534-2:2006, 3.3.3]

3.7
outlier
value from a set of values which is inconsistent with the other values of that set, identified by a statistical test

Note 1 to entry: ISO 5725-2 specifies the statistical tests and the significance *level* (3.3) to be used to identify outliers in trueness and precision experiments.

3.8
bias
difference between the expectation of the *test results* (3.1) and a true value

Note 1 to entry: Bias is the total systematic error as contrasted to random error. There can be one or more systematic error components contributing to the bias. A larger systematic difference from the accepted reference value is reflected by a larger bias value.

Note 2 to entry: The bias of a measuring instrument is normally estimated by averaging the error of indication over an appropriate number of repeated measurements. The error of indication is the ''indication of a measuring instrument minus a true value of corresponding input quantity''.

Note 3 to entry: In practice, the accepted reference value is substituted for the true value.

[SOURCE: ISO 3534-2:2006, 3.3.2]

3.9
bias of the measurement method
difference between the expectation of *test results* (3.1) obtained from all laboratories using the same method on identical test or measurement items and an *accepted reference value* (3.2)

Note 1 to entry: In practice, the bias of the measurement method is measured by the displacement of the average of results from a large number of different laboratories all using the same method. The bias of a measurement method can be different at different *levels* (3.3).

3.10
laboratory bias
difference between the expectation of the *test results* (3.1) obtained from a particular laboratory and an *accepted reference value* (3.2) under the conditions of a particular experiment

Note 1 to entry: It is assessed based on the performance of a particular laboratory.

3.11
laboratory component of bias B
difference between the *laboratory bias* (3.10) and the *bias of the measurement method* (3.9)

Note 1 to entry: The laboratory component of bias is specific to a given laboratory and the conditions of measurement within the laboratory, and also it can be different at different levels of the measurement method.

Note 2 to entry: The laboratory component of bias is relative to the overall average result, not the true or accepted reference value.

Note 3 to entry: Laboratory component of bias can be named effect of laboratory.

Note 4 to entry: The relationship between the laboratory bias, Δ, the bias of the measurement method, δ, and the laboratory component of the bias B is detailed in ISO 5725-4.

3.12
precision
closeness of agreement between independent *test results* (3.1) obtained under stipulated conditions

Note 1 to entry: Precision depends only on the distribution of random errors and does not relate to the true value or the specified value.

Note 2 to entry: The measure of precision is usually expressed in terms of imprecision and computed as a standard deviation of the test results. Less precision is reflected by a larger standard deviation.

Note 3 to entry: Quantitative measures of precision depend critically on the stipulated conditions. Repeatability and reproducibility conditions are particular sets of extreme conditions.

[SOURCE: ISO 3534-2:2006, 3.3.4]

3.13
repeatability
precision under *repeatability conditions* (3.14)

Note 1 to entry: Repeatability can be expressed quantitatively in terms of the dispersion characteristics of the results.

[SOURCE: ISO 3534-2:2006, 3.3.5]

3.14
repeatability conditions
observation conditions where independent *test results* (3.1) are obtained with the same method on identical test or measurement items in the same test or measuring facility by the same operator using the same equipment within short intervals of time

Note 1 to entry: Repeatability conditions include:

a) The same measurement procedure or test procedure;

b) The same operator;

c) The same measuring or test equipment used under the same conditions;

d) The same location;

e) Repetition over a short period of time.

[SOURCE: ISO 3534-2:2006, 3.3.6]

3.15
repeatability standard deviation
standard deviation of *test results* (3.1) obtained under *repeatability conditions* (3.14)

Note 1 to entry: It is a measure of dispersion of the distribution of test results under repeatability conditions.

Note 2 to entry: Similarly "repeatability variance" and "repeatability coefficient of variation" can be defined and used as measures of the dispersion of test results under repeatability conditions.

Note 3 to entry: Coefficient of variation should be used with caution. Variance or standard deviation is preferred.

[SOURCE: ISO 3534-2:2006, 3.3.7, modified — Note 3 to entry added.]

3.16
repeatability critical difference
value less than or equal to which the absolute difference between two final values, each of them representing a series of *test results* (3.1) obtained under *repeatability* (3.13), is expected to be with a specified probability

Note 1 to entry: Examples of final results are the mean and the median of the series of results; the series itself can consist of only one result.

[SOURCE: ISO 3534-2:2006, 3.3.8]

3.17
repeatability limit
r
repeatability critical difference (3.16) for a specified probability of 95 %

[SOURCE: ISO 3534-2:2006, 3.3.9]

3.18
reproducibility
precision under *reproducibility conditions* (3.19)

Note 1 to entry: Reproducibility can be expressed quantitatively in terms of the dispersion characteristics of the results.

Note 2 to entry: Results are usually understood to be corrected results.

[SOURCE: ISO 3534-2:2006, 3.3.10]

3.19
reproducibility conditions
observation conditions where independent *test results* (3.1) are obtained with the same method on identical test or measurement items in different test or measurement facilities with different operators using different equipment

[SOURCE: ISO 3534-2:2006, 3.3.11]

3.20
reproducibility standard deviation
standard deviation of *test results* (3.1) obtained under *reproducibility conditions* (3.19)

Note 1 to entry: It is a measure of the dispersion of the distribution of test results under reproducibility conditions.

Note 2 to entry: Similarly a "reproducibility variance" and "reproducibility coefficient of variation" can be defined and used as measures of the dispersion of test results under reproducibility conditions.

[SOURCE: ISO 3534-2:2006, 3.3.12]

3.21
reproducibility critical difference
value less than or equal to which the absolute difference between two final values, each of them representing a series of *test results* (3.1) obtained under *reproducibility conditions* (3.19), is expected to be with a specified probability

Note 1 to entry: Instances of final results are the mean and the median of the series of test results, the series itself can consist of only one test result.

[SOURCE: ISO 3534-2:2006, 3.3.13]