INTERNATIONAL STANDARD

ISO 17123-1

Second edition
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Optics and optical instruments — Field procedures for testing geodetic and surveying instruments —

Part 1: **Theory**

Optique et instruments d'optique — Méthodes d'essai sur site pour les instruments géodésiques et d'observation —

Partie 1: Théorie

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17123-1 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

This second edition cancels and replaces the first edition (ISO 17123-1:2002), which has been technically revised.

ISO 17123 consists of the following parts, under the general title *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments*:

— *Part 1: Theory*

— *Part 2: Levels*

— *Part 3: Theodolites*

— *Part 4: Electro-optical distance meters (EDM instruments)*

— *Part 5: Electronic tacheometers*

— *Part 6: Rotating lasers*

— *Part 7: Optical plumbing instruments*

— *Part 8: GNSS field measurement systems in real-time kinematic (RTK)*

Introduction

This part of ISO 17123 specifies field procedures for adoption when determining and evaluating the uncertainty of measurement results obtained by geodetic instruments and their ancillary equipment, when used in building and surveying measuring tasks. Primarily, these tests are intended to be field verifications of suitability of a particular instrument for the immediate task. They are not proposed as tests for acceptance or performance evaluations that are more comprehensive in nature.

The definition and concept of uncertainty as a quantitative attribute to the final result of measurement was developed mainly in the last two decades, even though error analysis has already long been a part of all measurement sciences. After several stages, the CIPM (Comité Internationale des Poids et Mesures) referred the task of developing a detailed guide to ISO. Under the responsibility of the ISO Technical Advisory Group on Metrology (TAG 4), and in conjunction with six worldwide metrology organizations, a guidance document on the expression of measurement uncertainty was compiled with the objective of providing rules for use within standardization, calibration, laboratory, accreditation and metrology services. ISO/IEC Guide 98-3 was first published as an International Standard (ISO document) in 1995.

With the introduction of uncertainty in measurement in ISO 17123 (all parts), it is intended to finally provide a uniform, quantitative expression of measurement uncertainty in geodetic metrology with the aim of meeting the requirements of customers.

ISO 17123 (all parts) provides not only a means of evaluating the precision (experimental standard deviation) of an instrument, but also a tool for defining an uncertainty budget, which allows for the summation of all uncertainty components, whether they are random or systematic, to a representative measure of accuracy, i.e. the combined standard uncertainty.

ISO 17123 (all parts) therefore provides, for defining for each instrument investigated by the procedures, a proposal for additional, typical influence quantities, which can be expected during practical use. The customer can estimate, for a specific application, the relevant standard uncertainty components in order to derive and state the uncertainty of the measuring result.

Optics and optical instruments — Field procedures for testing geodetic and surveying instruments —

Part 1:
Theory

1 Scope

This part of ISO 17123 gives guidance to provide general rules for evaluating and expressing uncertainty in measurement for use in the specifications of the test procedures of ISO 17123-2, ISO 17123-3, ISO 17123-4, ISO 17123-5, ISO 17123-6, ISO 17123-7 and ISO 17123-8.

ISO 17123-2, ISO 17123-3, ISO 17123-4, ISO 17123-5, ISO 17123-6, ISO 17123-7 and ISO 17123-8 specify only field test procedures for geodetic instruments without ensuring traceability in accordance with ISO/IEC Guide 99. For the purpose of ensuring traceability, it is intended that the instrument be calibrated in the testing laboratory in advance.

This part of ISO 17123 is a simplified version based on ISO/IEC Guide 98-3 and deals with the problems related to the specific field of geodetic test measurements.

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 Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 99 and the following apply.

3.1 General metrological terms

3.1.1
(measurable) quantity
property of a phenomenon, body or substance, where the property has a magnitude that can be expressed as a number and a reference

EXAMPLE 1 Quantities in a general sense: length, time, temperature.

EXAMPLE 2 Quantities in a particular sense: length of a rod.

3.1.2
value
value of a quantity
quantity value
number and reference together expressing the magnitude of a quantity

EXAMPLE Length of a rod: 3,24 m.

3.1.3
true value
true value of a quantity
true quantity value
value consistent with the definition of a given quantity

NOTE This is a value that would be obtained by perfect measurement. However, this value is in principle and in practice unknowable.

3.1.4
reference value
reference quantity value
quantity value used as a basis for comparison with values of quantities of the same kind

NOTE A reference quantity value can be a true quantity value of the measurand, in which case it is normally unknown. A reference quantity value with associated measurement uncertainty is usually provided by a reference measurement procedure.

3.1.5
measurement
process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

NOTE Measurement implies comparison of quantities and includes counting of entities.

3.1.6
measurement principle
phenomenon serving as the basis of a measurement (scientific basis of measurement)

NOTE The measurement principle can be a physical phenomenon like the Doppler effect applied for length measurements.

3.1.7
measurement method
generic description of a logical organization of operations used in a measurement

NOTE Methods of measurement can be qualified in various ways, such as “differential method” and “direct measurement method”.

3.1.8
measurand
quantity intended to be measured

EXAMPLE Coordinate x determined by an electronic tacheometer.

3.1.9
indication
quantity value provided by a measuring instrument or measuring system

NOTE An indication and a corresponding value of the quantity being measured are not necessarily values of quantities of the same kind.

3.1.10
measurement result
result of measurement
set of quantity values attributed to a measurand together with any other available relevant information

NOTE A measuring result can refer to

— the indication,

— the uncorrected result, or

— the corrected result.

A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty.

3.1.11
measured quantity value
quantity value representing a measurement result

3.1.12
error
error of measurement
measurement error
measured quantity value minus a reference quantity value

3.1.13
random measurement error
random error
component of measurement error that in replicate measurements varies in an unpredictable manner

NOTE Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance.

3.1.14
systematic error
systematic error of measurement
component of measurement error that in replicate measurements remains constant or varies in a predictable manner

NOTE Systematic error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement error.

3.2 Terms specific to this International Standard

3.2.1
accuracy of measurement
closeness of agreement between a measured quantity value and the true value of the measurand

NOTE 1 "Accuracy" is a qualitative concept and cannot be expressed in a numerical value.

NOTE 2 "Accuracy" is inversely related to both systematic error and random error.

3.2.2
experimental standard deviation
estimate of the standard deviation of the relevant distribution of the measurements

NOTE 1 The experimental standard deviation is a measure of the uncertainty due to random effects.

NOTE 2 The exact value arising in these effects cannot be known. The value of the experimental standard deviation is normally estimated by statistical methods.

3.2.3
precision
measurement precision
closeness of agreement between measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions

NOTE Measurement precision is usually expressed by measures of imprecision, such as experimental standard deviation under specified conditions of measurement.

3.2.4
repeatability condition
repeatability condition of measurement
condition of measurement, out of a set of conditions

NOTE Conditions of measurement include

- the same measurement procedure,
- the same observer(s),
- the same measuring system,
- the same meteorological conditions,
- the same location, and
- replicate measurements on the same or similar objects over a short period of time.

3.2.5
repeatability
measurement repeatability
measurement precision under a set of repeatability conditions of measurement

3.2.6
reproducibility conditions of measurement
condition of measurement, out of a set of conditions

NOTE Conditions of measurement include

- different locations,
- different observers,
- different measuring systems, and
- replicate measurements on the same or similar objects.

3.2.7
reproducibility
measurement reproducibility
measurement precision under reproducibility conditions of measurement

3.2.8
influence quantity
quantity, which in a direct measurement does not affect the quantity that is actually measured, but affects the relation between the indication of a measuring system and the measurement result

EXAMPLE Temperature during the length measurement by an electronic tacheometer.

3.3 The term “uncertainty”

3.3.1
uncertainty
uncertainty of measurement
measurement uncertainty
non-negative parameter characterizing the dispersion of quantity values attributed to a measurand, based on the information used

NOTE Measurement uncertainty comprises, in general, many components. Some of these components can be evaluated by a Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by an experimental standard deviation. The other components, which can be evaluated by a Type B evaluation of measurement uncertainty, can also be characterized by an approximation to the corresponding standard deviations, evaluated from assumed probability distributions based on experience or other information.

3.3.2
Type A evaluation
Type A evaluation of measurement uncertainty
evaluation of a component of measurement uncertainty (standard uncertainty) by a statistical analysis of quantity values obtained by measurements under defined measurement conditions

NOTE For information about statistical analysis, see 4.1 and ISO/IEC Guide 98-3.

3.3.3
Type B evaluation of measurement uncertainty
evaluation of a component of measurement uncertainty (standard uncertainty) determined by means other than a Type A evaluation of measurement uncertainty

EXAMPLE The component of measurement uncertainty can be based on

— previous measurement data,

— experience with, or general knowledge of, the behaviour and property of relevant instruments or materials,

— manufacturer's specifications,

— data provided in calibration and other reports,

— uncertainties assigned to reference data taken from handbooks, and

— limits deduced through personal experiences.

NOTE For more information see 4.3 and ISO/IEC Guide 98-3.

3.3.4
standard uncertainty
standard uncertainty of measurement
standard measurement uncertainty
measurement uncertainty expressed as a standard deviation

NOTE Standard uncertainty can be estimated either by a Type A evaluation or by a Type B evaluation.

3.3.5
combined standard uncertainty
combined standard measurement uncertainty
standard (measurement) uncertainty, obtained by using the individual standard uncertainties (and covariances as appropriate), associated with the input quantities in a measurement model

NOTE The procedure for combining standard uncertainties is often called the “law of propagation of uncertainties” and in common parlance the “root-sum-of-squares” (RSS) method.

3.3.6
coverage factor
numerical factor larger than one, used as a multiplier of the (combined) standard uncertainty in order to obtain the expanded uncertainty

NOTE The coverage factor, which is typically in the range of 2 to 3, is based on the coverage probability or level of confidence required of the interval.

3.3.7
expanded uncertainty
expanded measurement uncertainty
half-width of a symmetric coverage interval, centred around the estimate of a quantity with a specific coverage probability

NOTE A fraction can be viewed as the coverage probability or level of confidence of the interval.

3.3.8
coverage interval
interval containing the set of true quantity values of a measurand with a stated probability, based on the information available

NOTE It is intended that a coverage interval not be termed “confidence interval” in order to avoid confusion with the statistical concept. To associate an interval with a specific level of confidence requires explicit or implicit assumptions regarding the probability distribution, characterized by the measurement result.

3.3.9
coverage probability

probability that the set of true quantity values of a measurand is contained within a specific coverage interval

NOTE The probability is sometimes termed “level of confidence” (see ISO/IEC Guide 98-3).

3.3.10
uncertainty budget
statement of a measurement uncertainty, of the components of that measurement uncertainty, and of their calculation and combination

NOTE It is intended that an uncertainty budget include the measurement model, estimates, measurement uncertainties associated with the quantities in the measurement model, type of applied probability density functions and type of evaluation of measurement uncertainty.

3.3.11
measurement model
mathematical relation among all quantities known to be involved in a measurement

3.4 Symbols

Table 1 — Symbols and definitions

a	Half-width of a rectangular distribution of possible values of input quantity X_i:$a = (a_+ - a_-)/2$
a_+	Upper bound or upper limit of input quantity X_i
a_-	Lower bound or lower limit of input quantity X_i
A	Design or Jacobian matrix ($N \times n$)
c_i	Partial derivates or sensitive coefficient: $c_i = \dfrac{\partial f}{\partial x_i}$ ($i = 1, 2, ..., N$)
$\boldsymbol{c}$	Vector of sensitive coefficients c_i ($i = 1, 2, ..., N$)
$\boldsymbol{e}$	Unit vector
f_k	Functional relationship between a measurand, Y_k, and the input quantity, X_j, and between output estimate, y_k, and input estimates, x_j
$\boldsymbol{f}$	Vector with elements $f_k(\boldsymbol{x}^T)$ ($k = 1, 2, ..., n$)
$F_{1-\alpha/2}(\nu, \nu)$	Fisher's F (or Fisher-Snedecor) distribution with degrees of freedom (ν, ν) and confidence level of $(1 - \alpha)$ %
g_j	Functional relationship between the estimate of input quantity, x_j, and the observables, l_i
k	Coverage factor used to calculate expanded uncertainty $U = k \times u_c(y)$ of the output estimate y from its combined uncertainty $u_c(y)$
l_i	Observables, random variables ($i = 1, 2, ..., m$)
m	Number of observations, l_i
M	Number of input quantities, whose uncertainties can be estimated by a Type A evaluation
n	Number of output quantities, measurands
N	Number of input quantities
$N - M$	Number of input quantities, whose uncertainties can be estimated by a Type B evaluation
$\boldsymbol{N}$	Normal equation matrix ($n \times n$)
p_j	Weight of the input estimates x_j ($j = 1, 2, ..., N$)
$\boldsymbol{P}$	Weight matrix of p_j ($N \times N$)
Q_{ykyk}	Cofactor of the output estimate, y_k
$\boldsymbol{Q}_y$	Cofactor matrix of the output estimates, y_k ($n \times n$)
r_j	Residual of input estimates, x_j ($j = 1, 2, ..., N$)
$\boldsymbol{r}$	Vector of residuals, r_j
$r(x_i, x_j)$	Correlation coefficient between the input estimates, x_i and x_j
s	Experimental standard deviation (general notation)
$s(y_k)$	Experimental standard deviation of the output estimate y_k
$t_\alpha(\nu)$	Student's t-distribution with the degree of freedom, ν, and a confidence level of $(1 - \alpha)$ %
u	Standard uncertainty (general notation)
$u(y_k)$	Standard uncertainty of the output estimate y_k
$u(x_j)$	Standard uncertainty of the input estimate x_j
$u_c(y_k)$	Combined standard uncertainty of the output estimate y_k
U	Expanded uncertainty (general notation)