INTERNATIONAL STANDARD

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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 3.

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 part of ISO 17123 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 optical instruments*, Subcommittee SC 6, *Geodetic and surveying instruments*.

This part of ISO 17123 cancels and replaces ISO 8322-1:1989, 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*

Annex A of this part of ISO 17123 is for information only.

Introduction

ISO 17123 specifies field procedures to be adopted when determining and evaluating the precision of geodetic instruments and their ancillary equipment when used in building and surveying measurements. Primarily, these tests are intended to be field verifications of the suitability of a particular instrument for the immediate task at hand and to satisfy the requirements of other standards. They are not proposed as tests for acceptance or performance evaluations that are more comprehensive in nature.

ISO 17123 can be thought of as one of the first steps in the process of evaluating the uncertainty of a measurement (more specifically a measurand). The uncertainty of a result of a measurement is dependent on a number of factors. These include, among others, repeatability, reproducibility (between day repeatability) and a thorough assessment of all possible error sources, as prescribed by the ISO Guide to the expression of uncertainty in measurement (GUM).

These field procedures have been developed specifically for *in situ* applications without the need for special ancillary equipment and are purposely designed to minimize atmospheric influences.

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

Part 1: **Theory**

1 Scope

This part of ISO 17123 gives the theory used in the specification of the test procedures of the other parts of ISO 17123. These procedures assume the use of measuring methods in which systematic influences can be largely compensated or disregarded.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 17123. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 17123 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms*

ISO 4463-1, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria*

ISO 7077, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance*

ISO 7078, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes*

GUM, *Guide to the expression of uncertainty in measurement*

VIM, *International vocabulary of basic and general terms in metrology* (BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML)

3 Terms and definitions

For the purposes of this part of ISO 17123, the terms and definitions given in ISO 3534-1, ISO 4463-1, ISO 7077, ISO 7078, GUM and VIM apply.

4 Expression of the precision of geodetic and surveying instruments

The measure of precision of a geodetic and surveying instrument is expressed in terms of the experimental standard deviation, σ (root mean square error), or the variance, σ^2. The variance, s^2, of a sample is an estimator for the (theoretical) variance, σ^2, of the population. Bases of the estimation of σ^2 are:

a) The deviations, ε , of the measured values from the corresponding true values (or values considered to be true)

$$s^2 = \frac{\sum_{j=1}^{n} \varepsilon_j^2}{n} \tag{1}$$

where

n is the number of the measured values.

b) The deviations, r (residuals), of the measured values from the corresponding estimated parameters

$$s^2 = \frac{\sum_{j=1}^{n} r_j^2}{\nu} \tag{2}$$

where

ν is the number of degrees of freedom, i.e. the number of measurements minus the number of estimated parameters. In the simplest case, these are only arithmetic means of the measurements. Sometimes, zero-point corrections or other parameters shall be provided additionally.

c) The differences, d, of double measurements (two measurements with the same measurand)

$$s^2 = \frac{\sum_{j=1}^{n} d_j^2}{2n} \tag{3}$$

where

n is the number of pairs of measurements.

If the contract documentation specifies the permitted deviation for the measuring task, ISO 4463-1 recommends that the experimental standard deviation satisfy:

$$s \leqslant \frac{|p|}{2{,}5} \tag{4}$$

where

$\pm p$ is the permitted deviation (according to ISO 4463-1);

s is the measure of precision in use expressed as the experimental standard deviation.

p is compared with the measure of precision in use obtained either from previous precision in use tests, or from general data which indicate the expected precision in use of the given measuring equipment. In these cases, the experimental standard deviation, s, representing the measure of precision in use associated with the given measuring equipment exceeds the specified permitted deviation of the measuring task; consideration should be given to either selecting a different procedure and/or a more precise instrument, or to discuss with the designer the need for such a small permitted deviation, p.

Most of the other parts of ISO 17123 describe a simplified and a full test procedure for geodetic and surveying instruments.

5 Equations

5.1 General

The following equations are required for use at the evaluation stage of most of the procedures given in the subsequent clauses of this part of ISO 17123. They indicate how the achieved measure of precision, expressed in terms of the standard deviation (root mean square error), is estimated by first calculating the individual standard deviations for each of the series of measurements and then by combining statistically each of these individual standard deviations. The equations are given in general terms such that the number, m, of the series of measurements, the number, n, of individual measurements within each series, and the number, ν, of degrees of freedom are not defined explicitly (see ISO 3534-1).

5.2 Calculation of the standard deviation for the i^{th} series of measurements using values accepted as true

$$\varepsilon_{i,j} = \bar{x}_i - x_{i,j} \tag{5}$$

where

$\varepsilon_{i,j}$ is the deviation of the j^{th} measurement of the i^{th} series from the true value or the corresponding value accepted as true;

$\bar{x}_i$ is the true value or the value accepted as true of the i^{th} series, derived from another measurement procedure with an uncertainty so small that it can be ignored;

$x_{i,j}$ is the j^{th} measurement of the i^{th} series.

$$\Sigma\varepsilon_i^2 = \sum_{j=1}^{n} \varepsilon_{i,j}^2 = \varepsilon_{i,1}^2 + \varepsilon_{i,2}^2 + \cdots + \varepsilon_{i,n}^2 \tag{6}$$

where

n is the number of measurements in the i^{th} series;

$\Sigma\varepsilon_i^2$ is the sum of squares of all true deviations $\varepsilon_{i,j}$ (or the corresponding values, accepted as true) within the i^{th} series of measurements.

$$s_i = \sqrt{\frac{\Sigma\varepsilon_i^2}{\nu_i}} \tag{7}$$

where

ν_i is the number of degrees of freedom ($\nu_i = n$) for the i^{th} series of measurements;

s_i is the experimental standard deviation for the i^{th} series of measurements.

5.3 Calculation of the experimental standard deviation for the i^{th} series of measurements using mean values

$$\bar{x}_i = \frac{1}{n}\sum_{j=1}^{n} x_{i,j} \tag{8}$$

where

n is the number of measurements in the i^{th} series;

$x_{i,j}$ is the j^{th} measurement of the i^{th} series;

$\bar{x}_i$ is the arithmetic mean of the measurements $x_{i,j}$ within the i^{th} series of measurements.

$$r_{i,j} = \bar{x}_i - x_{i,j} \tag{9}$$

where

$r_{i,j}$ is the deviation (residual) of the measurement, $x_{i,j}$, from the arithmetic mean, $\bar{x}_i$.

To minimize the effect of rounding errors, the calculation of each division should be carried out to the nearest 0,1 value of the last observed digit.

As an arithmetic check, the sum of the deviations, $r_{i,j}$, shall be zero, except for rounding errors.

$$\Sigma r_i^2 = \sum_{j=1}^{n} r_{i,j}^2 = r_{i,1}^2 + r_{i,2}^2 + \cdots + r_{i,n}^2 \tag{10}$$

where

Σr_i^2 is the sum of squares of all deviations, $r_{i,j}$, within the i^{th} series of measurements.

$$\nu_i = n - 1 \tag{11}$$

where

ν_i is the number of degrees of freedom for the i^{th} series of measurements where the arithmetic mean of the measured values is the only parameter to be estimated.

$$s_i = \sqrt{\frac{\Sigma r_i^2}{\nu_i}} \tag{12}$$

where

s_i is the experimental standard deviation for the i^{th} series of measurements.

5.4 Calculation of the experimental standard deviation for the i^{th} series of measurements by adjustment

$$\Sigma r_i^2 = \sum_{j=1}^{n} r_{i,j}^2 = r_{i,1}^2 + r_{i,2}^2 + \cdots + r_{i,n}^2 \tag{13}$$

where

n is the number of measurements in the i^{th} series;

$r_{i,j}$ the residual of the value, $x_{i,j}$, resulting from the adjustment of the i^{th} series of measurements (see other parts of ISO 17123). To reduce rounding errors, this adjustment should be carried out with sufficient numerical precision;

Σr_i^2 is the sum of squares of all residuals, $r_{i,j}$, within the i^{th} series of measurements.

$$\nu_i = n - u \tag{14}$$

where

u is the number of parameters to be estimated (unknowns);

ν_i is the number of degrees of freedom of the i^{th} series of measurements.

$$s_i = \sqrt{\frac{\Sigma r_i^2}{\nu_i}} \tag{15}$$

where

s_i is the experimental standard deviation for the i^{th} series of measurements.

5.5 Calculation of the experimental standard deviation for the i^{th} series of measurements using double measurements

$$d_{i,j} = x_{i,j,1} - x_{i,j,2} \tag{16}$$

where

$x_{i,j,1}$ and $x_{i,j,2}$ are the values of the j^{th} set of double measurements within the i^{th} series of double measurements;

$d_{i,j}$ is the difference of the two corresponding values of the double measurements of the j^{th} set of the i^{th} series of double measurements.

$$\Sigma d_i^2 = \sum_{j=1}^{n} d_{i,j}^2 = d_{i,1}^2 + d_{i,2}^2 + \cdots + d_{i,n}^2 \tag{17}$$

where

n is the number of measurements of the j^{th} set within a double measurement in the i^{th} series of double measurements;