FINAL DRAFT
International Standard

ISO/FDIS 17123-6

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

Part 6: Rotating lasers

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

Partie 6: Lasers rotatifs

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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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

This fourth edition cancels and replaces the third edition (ISO 17123-6:2022), which has been technically revised.

The main changes are as follows:

— the first paragraph of Introduction has been deleted as already cited as first paragraph of the Scope;

— more flexible configuration of the test line and updating of the mathematical model;

— harmonization of terminology and symbols;

— correction of errors.

A list of all parts in the ISO 17123 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

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 International 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 the Guide to the Expression of Uncertainty in Measurement (GUM) 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 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 6:
Rotating lasers

1 Scope

This document specifies field procedures to be adopted when determining and evaluating the precision (repeatability) of rotating lasers, the uncertainty of measurement results obtained by geodetic instruments and their ancillary equipment, particularly when used in building and surveying measurements for levelling tasks. 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.

This document can be considered 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 parameters. Therefore, this document differentiates between various quality measures and testing objectives, including repeatability and reproducibility (between-day repeatability), and provides a thorough assessment of all potential error sources, as specified by ISO/IEC Guide 98-3 and ISO 17123-1.

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

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 dated references, only the edition cited applies. 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 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, *Buildings and civil engineering works — Procedures for setting out, measurement and surveying — Vocabulary*

ISO 9849, *Optics and optical instruments — Geodetic and surveying instruments — Vocabulary*

ISO 17123-1, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 1: Theory*

ISO 17123-2, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 2: Levels*

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

ISO/IEC Guide 99, *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 3534-1, ISO 4463-1, ISO 7077, ISO 7078, ISO 9849, ISO 17123-1, ISO 17123-2, ISO/IEC Guide 98-3 and ISO/IEC Guide 99 apply.

ISO and IEC maintain terminology 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/

4 Symbols and abbreviated terms

4.1 Symbols

Symbol	Quantity	Unit
$\boldsymbol{A}$	design matrix	—
a	deflective deviation	m
b	deviation of the rotating axis	m
D	horizontal distance	m
$\bar{D}$	mean horizontal distance	m
$\tilde{d}$	single measured height difference between target points	m
$\bar{\boldsymbol{d}}$	vector of known height differences of target points	m
$\tilde{\boldsymbol{d}}$	vector of measured height differences of target points	m
h	height difference of levelling staff B and A	m
F	F (Fisher) distribution	—
f	number of target point	—
i	series of measurement	—
j	set of measurement	—
n	set of readings	—
$\boldsymbol{P}$	weight matrix of the observations	—
p	single weight factor	—
$\boldsymbol{Q}$	Cofactor matrix (inverse of the weight matrix $\boldsymbol{P}$)	—
$\boldsymbol{r}$	residual vector of the height differences	m
r	residual	m
s, $\tilde{s}$	experimental standard deviation	m
t	t-distribution	—
u	standard uncertainty	m
x	measured reading at levelling staff	m
$\boldsymbol{x}$	observation vector of height differences	m
$\tilde{\boldsymbol{y}}$	vector of unknown parameters	m
$\bar{\boldsymbol{y}}$	mean vector of unknown parameters	m
ν	degrees of freedom	—
α	significance level	%

Symbol	Quantity	Unit
σ	theoretical standard deviation	m
χ^2	chi-squared distribution	—
Ω	sum of residual squares	m^2

4.2 Abbreviations

Abbreviation	Description
A	levelling point A
Ang	Angle
B	levelling point B
ISO-ROLAS	ISO specific for rotation lasers
ISO	International Organization for Standardization
S	instrument station
x, *y*, *z*	cartesian coordinate

5 General

5.1 Requirements

Before commencing surveying, it is important that the operator investigates that the precision in use of the measuring equipment is appropriate to the intended measuring task.

The rotating laser and its ancillary equipment shall be in known and acceptable states of permanent adjustment according to the methods specified in the manufacturer's handbook, and used with tripods and levelling staffs as recommended by the manufacturer.

The results of these tests are influenced by meteorological conditions, especially by the temperature gradient. An overcast sky and low wind speed guarantee the most favourable weather conditions. The particular conditions to be taken into account may vary depending on the location where the tasks are to be undertaken. Note should also be taken of the actual weather conditions at the time of measurements and the type of surface above which the measurements are performed. The conditions chosen for the tests should match those expected when the intended measuring task is actually carried out (see ISO 7077 and ISO 7078).

This document describes two different field procedures as given in Clauses 6 and 7. The operator shall choose the procedure which is most relevant to the project's particular requirements.

5.2 Procedure 1: simplified test procedure

The simplified test procedure provides an estimate as to whether the precision of a given item of rotating-laser equipment is within the specified permitted deviation, according to ISO 4463-1.

This test procedure is normally intended for checking the precision (see ISO/IEC Guide 99:2007, 2.15) of a rotating laser to be used for area levelling applications, for tasks where measurements with unequal site lengths are common practice, e.g. building construction sites.

The simplified test procedure is based on a limited number of measurements. Therefore, a significant standard deviation and the standard uncertainty (Type A), respectively, cannot be obtained. If a more precise assessment of the rotating laser under field conditions is required, it is recommended to adopt the more rigorous full test procedure as given in Clause 7.

This test procedure relies on having a test field with height differences which are accepted as true values. If such a test field is not available, it is necessary to determine the unknown height differences (see Figures 1 and 2), using an optical level of accuracy (see ISO 17123-2) higher than the rotating laser required for the

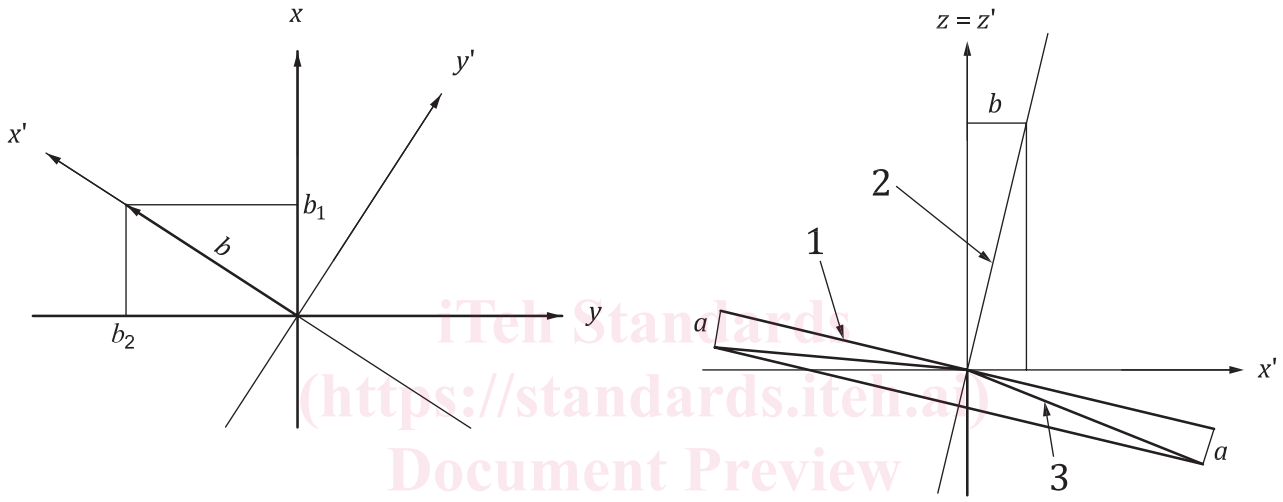
measuring task. If, however, a test field with known height differences cannot be established, it will be necessary to apply the full test procedure as given in Clause 7.

If no levelling instrument is available, the rotating laser to be tested can be used to determine the true values by measuring height differences between all points with central setups. At each setup, two height differences have to be observed by rotating the laser plane by 180°. The mean value of repeated readings in both positions will provide the height differences which are accepted as true.

5.3 Procedure 2: full test procedure

The full test procedure shall be adopted to determine the best achievable measure of precision of a particular rotating laser and its ancillary equipment under field conditions, by a single survey team.

Further, this test procedure serves to determine the deflective deviation, a, and both components, b_1 and b_2, of the deviation of the rotating axis from the true vertical, $b = \sqrt{{b_1}^2 + {b_2}^2}$ of the rotating laser (see Figure 1).



a) Horizontal plane (top view) **b) Vertical plane through x' (side view)**

Key

1 inclined plane
2 cone axis
3 inclined cone
[a] See Figure 5 also.

Figure 1 — Deflective deviations *a* and *b*

The recommended measuring distances within the test field (see Figure 3) are 40 m. Sight lengths greater than 40 m may be adopted for this precision-in-use test only, where the project specification may dictate, or where it is determining the range of the measure of precision of a rotating laser at respective distances.

The test procedure given in Clause 6 of this document is intended for determining the measure of precision in use of a particular rotating laser. This measure of precision in use is expressed in terms of the experimental standard deviation, s, of a height difference between the instrument level and a levelling staff (reading at the staff) at a certain distance. This experimental standard deviation corresponds to the standard uncertainty of Type A [see Formula (1)]:

$$s_{\text{ISO-ROLAS}} := u_{\text{ISO-ROLAS}} \tag{1}$$

Further, this procedure may be used to determine the standard uncertainty as a measure of precision in use of

— a single rotating laser and its ancillary equipment by a single survey team at a given time,

— a single rotating laser over time and differing environmental conditions, and

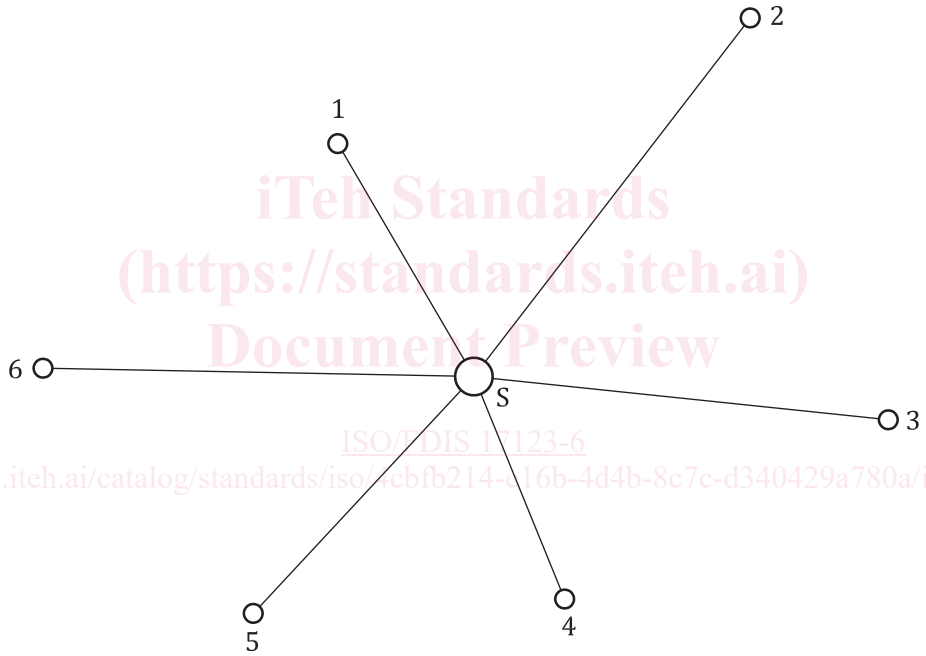
— several rotating lasers in order to enable a comparison of their respective achievable precisions to be obtained under similar field conditions.

Statistical tests should be applied to determine whether the experimental standard deviation, s, obtained belongs to the population of the instrumentation's theoretical standard deviation, σ, whether two tested samples belong to the same population, whether the deflective deviation, a, is equal to zero, and whether the deviation, b, of the rotating axis from the true vertical of the rotating laser is equal to zero.

6 Simplified test procedure

6.1 Configuration of the test field

To keep the influence of refraction as small as possible, a reasonably horizontal test area shall be chosen. Six fixed target points, 1, 2, 3, 4, 5 and 6, shall be used to cover each horizontal quadrant at least with one target and shall be set up in approximately the same horizontal plane at different distances, between 10 m and 60 m apart from the instrument station S. The directions from the instrument to the six fixed points shall be spread over the horizon as equally as possible (see Figure 2).



Key

S	instrument station
1, 2, 3, 4, 5, 6	fixed target points (f)

Figure 2 — Configuration of the test field for the simplified test procedure

To ensure reliable results, the target points shall be marked in a stable manner and reliably fixed during the test measurements, including repeat measurements.

The height differences between the six fixed points, 1 to 6, shall be determined using an optical level of known high accuracy as described in Clause 5.