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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.

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 17123-6 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 17123-6:2003), 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 measurements to reflectors)*

— *Part 5: Total stations*

— *Part 6: Rotating lasers*

— *Part 7: Optical plumbing instruments*

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

Annexes A, B and C of this part of ISO 17123 are for information only.

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 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 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 6: **Rotating lasers**

1 Scope

This part of ISO 17123 specifies field procedures to be adopted when determining and evaluating the precision (repeatability) of rotating lasers and their ancillary equipment 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 part of 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 parameters. Therefore this part of ISO 17123 differentiates between different measures of accuracy and objectives in testing, like repeatability and reproducibility (between-day repeatability), and of course gives a thorough assessment of all possible error sources, as prescribed 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 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 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, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes*

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.

4 General

4.1 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 part of ISO 17123 describes two different field procedures as given in Clauses 5 and 6. The operator shall choose the procedure which is most relevant to the project's particular requirements.

4.2 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 6.

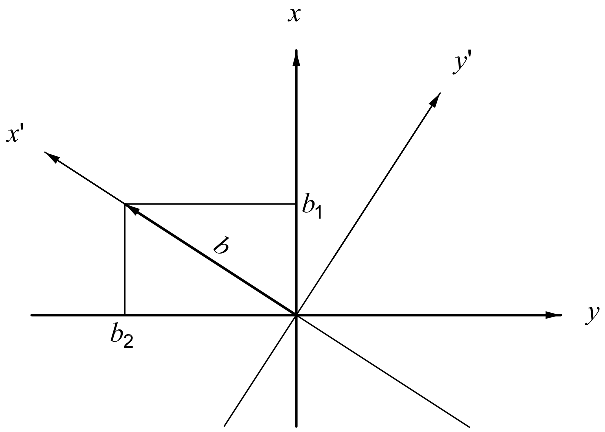
This test procedure relies on having a test field with height differences which are accepted as true values. If such a test field is not available, it is necessary to determine the unknown height differences (see Figures 1 and 2), using an optical level of accuracy (see ISO 17123-2) higher than the rotating 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 6.

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.

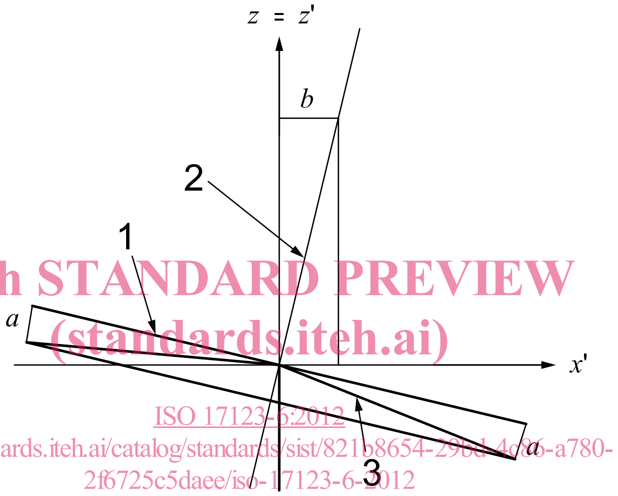
4.3 Procedure 2: Full test procedure

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

Figure 1 — Deflective deviations a and b (see Figure 5)

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 part of ISO 17123 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 distance of 40 m. This experimental standard deviation corresponds to the standard uncertainty of Type A:

$$s_{\text{ISO-ROLAS}} = u_{\text{ISO-ROLAS}}$$

Further, this procedure may be used to determine:

— the standard uncertainty as a measure of precision in use of rotating lasers by a single survey team with a single instrument and its ancillary equipment at a given time;

— the standard uncertainty as a measure of precision in use of a single instrument over time and differing environmental conditions;

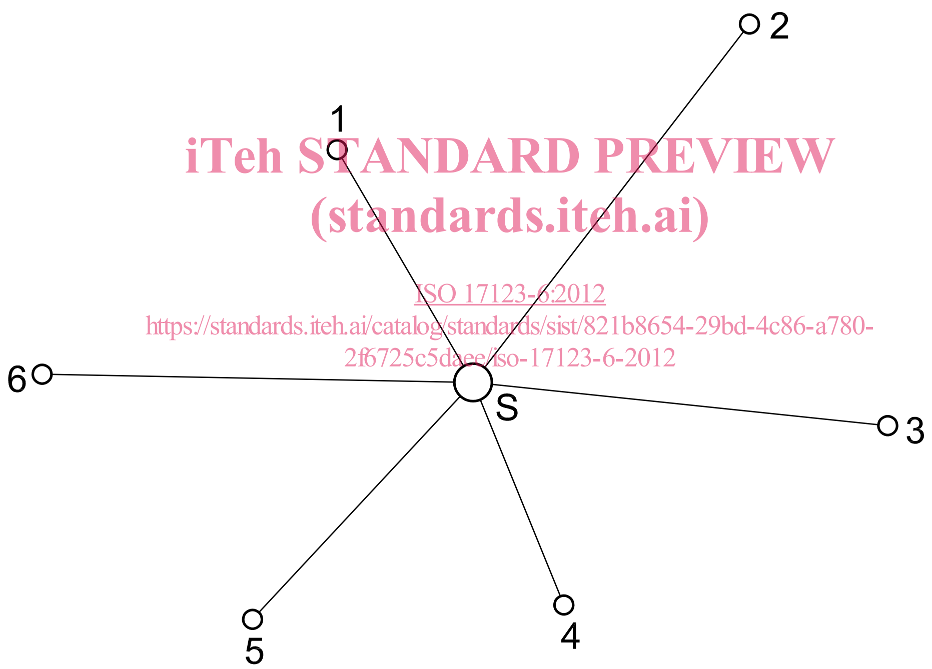
— the standard uncertainties as a measure of precision in use of several rotating lasers in order to enable a comparison of their respective achievable precisions to be obtained under similar field conditions.

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.

5 Simplified test procedure

5.1 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 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

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, 2, 3, 4, 5 and 6, shall be determined using an optical level of known high accuracy as described in Clause 4.

The following five height differences between the $t = 6$ target points are known:

$$\bar{d} = \begin{pmatrix} \bar{d}_{2,1} \\ \vdots \\ \bar{d}_{t,t-1} \end{pmatrix} \quad t = 2, \ldots 6 \qquad (1)$$

5.2 Measurements

The instrument shall be set up in a stable manner above point S. Before commencing the measurements, the laser beam shall become steady. To ensure that the laser plane of the instrument remains unchanged during the whole measuring cycle, a fixed target shall be observed before and after each set, j, of measurements, ($j = 1, \ldots, 5$).

Six separate readings, $x_{j,1}$ to $x_{j,6}$, on the scale of the levelling staff shall be carried out to each fixed target point, 1, 2, 3, 4, 5 and 6. Between two sets of readings the instrument shall be lifted, turned clockwise approximately 70°, placed in a slightly different position and relevelled. The time between any two sets of readings shall be at least 10 minutes.

Each reading shall be taken in a precise mode according to the recommendations of the manufacturer.

5.3 Calculation

The evaluation of the readings x_t for each set j is based on the following differences:

$$\begin{pmatrix} d_{j,2,1} \\ \vdots \\ d_{j,t,t-1} \end{pmatrix} = \begin{pmatrix} x_{j,2} - x_{j,1} \\ \vdots \quad - \quad \vdots \\ x_{j,t} - x_{j,t-1} \end{pmatrix} \quad j = 1, \ldots, 5 \quad and \quad t = 2, \ldots 6 \tag{2}$$

respectively

$$d_j = x_{j,t} - x_{j,t-1} \tag{3}$$

where

t is the number of the target point.

Calculating $\bar{d}$, the mean of the differences d_j, the residual vector of the height differences in set j is obtained by

$$r_j = \bar{d} - d_j \quad j = 1, \ldots, 5 \tag{4}$$

Finally the sum of the residual squares of all five sets yields

$$\sum r^2 = \sum_{j=1}^{5} r_j^T r_j \; . \tag{5}$$

$\nu = 5 \times (6 - 1) = 25$ is the corresponding number of degrees of freedom.

$$s = \sqrt{\frac{\sum r^2}{\nu}} = u_{\text{ISO}} \tag{6}$$

where s is the experimental standard deviation and u_{ISO} the standard uncertainty (Type A) of a single measured height difference, $d_{j,t,t-1}$, between two points of the test field. This represents in this part of ISO 17123 a measure of precision relative to the standard uncertainty of a Type A evaluation. This value includes systematic and random errors.

6 Full test procedure

6.1 Configuration of the test line

To keep the influence of refraction as small as possible, a reasonably horizontal test area shall be chosen. The ground shall be compact and the surface shall be uniform; roads covered with asphalt or concrete shall be avoided. If there is direct sunlight, the instrument and the levelling staffs shall be shaded, for example by an umbrella.

Two levelling points, A and B, shall be set up approximately 40 m apart. To ensure reliable results, the levelling staffs shall be set up in stable positions, reliably fixed during the test measurements, including any repeat measurements. The instrument shall be placed at the positions S1, S2 and S3. The distances from the instrument's positions to the levelling points shall be in accordance with Figure 3. The position S1 shall be chosen equidistant between the levelling points, A and B (40/2 = 20 m).

Dimensions in metres

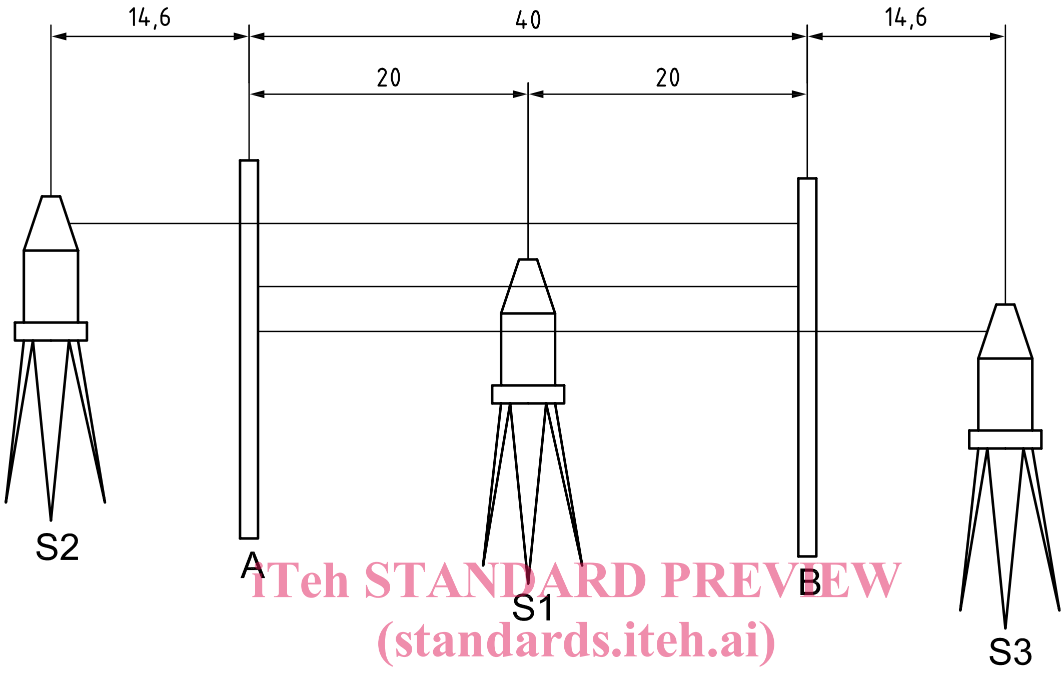


Figure 3 — Configuration of the test line for the full test procedure

6.2 Measurements

Before commencing the measurements, the instrument shall be adjusted as specified by the manufacturer.

For the full test procedure, $i = 4$ series of measurements should be performed. In each series, three instrument setups S1, S2 and S3 are chosen, according to the configuration given in Figure 3. At any setup $n = 4$ sets of readings are taken. Each set consists of two readings x_{Aj}, and x_{Bj}, namely to rod A and to rod B. After each set, the orientation of the instrument has to be changed clockwise about 90° (see Figure 4). Hence one series consists of $j = 3 \times 4 = 12$ readings for each rod. In order to ensure that the instrument deviation b is aligned properly during the measurements, the instrument has to be oriented at the three positions S1, S2 and S3 in the same direction and the sense of rotation has to be maintained.

With each new setup of the chosen reference direction (reference marks on the tripod head), the instrument shall be relevelled carefully. If the instrument is provided with a compensator, care shall be taken that it functions properly. It is recommended to assign the four orientations of the instrument on the ground plate. The numbering of the 12 measurements can be represented for each measuring set as shown in Figure 4. All readings shall be taken in a precise mode according to the recommendations of the manufacturer.