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Optics and optical instruments — Laboratory procedures for testing surveying and construction instruments —

Part 1: Performance of handheld laser distance meters

Optique et instruments d'optique — Méthodes d'essai de laboratoire des instruments d'observation et construction —

Partie 1: Performance de télémètres laser de poche

Reference number
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Foreword

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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 documents 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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

This second edition cancels and replaces the first edition (ISO 16331-1:2012), which has been technically revised.

A list of all parts in the ISO 16331 series can be found on the ISO website.

Introduction

Starting in 1993, several companies developed handheld laser distance meters and introduced them into the market. With a growing number of different manufacturers, it became obvious that a standard was needed to establish requirements for device specifications and to describe how to check compliance with the specified performance of accuracy and range.

ISO 17123 specifies methods of checking specification compliance by the user of the instrument without any additional measurement equipment. In contrast, ISO 16331 specifies procedures to check specification compliance using additional laboratory equipment that is unavailable to the typical user.

Optics and optical instruments — Laboratory procedures for testing surveying and construction instruments —

Part 1: Performance of handheld laser distance meters

1 Scope

This document specifies procedures for checking compliance with performance specifications of handheld laser distance meters.

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

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 9849, ISO/IEC Guide 98-3 and ISO/IEC Guide 99 apply.

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

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

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

4 Symbols and abbreviated terms

Table 1 — Symbols

D	distance
$\overline{D}$	mean value of a set of distances
Δ	deviation
k	coverage factor for a level of confidence of 95 %
M	measurement value
N	number of measurements taken at each check point

Table 1 *(continued)*

R	resolution
s	experimental standard deviation
u	standard uncertainty of measurement
U	expanded uncertainty

Table 2 — Subscripts and abbreviated terms

AD	absolute distance
Add	additional contribution
BG	background illumination
CP *X*	check point *X*
REF	reference
M	measurement
max	maximum
min	minimum
high	high
low	low
C	combined
CP	checkpoint
i	index for individual cases
RM	measurement resolution
RT	range test
X	index for individual cases
T	temperature
T05	temperature 5 °C
T40	temperature 40 °C

5 General information

5.1 General

The maximum measurement range on typical targets (info and examples, see Annex F) and the uncertainty of measurements provided by handheld laser distance meters are influenced by the following factors.

5.2 Target reflectivity

The higher the target reflectivity, the better the signal to noise ratio at the receiver; therefore better measurement performance is achievable. For more details, refer to Annex F.

As handheld laser distance meters are used on construction sites and for indoor applications, typical targets are painted walls, bricks, concrete, wood, and similar targets. Special attention has to be paid to the effect of penetration of the laser into certain materials, e.g. white marble.

5.3 Background illumination

Background light in indoor applications is typically below 3 klx and therefore negligible. However, in outdoor applications, the sunlight reflected by the target might reach an illuminance of up to 100 klx and might cause a degradation of the signal to noise ratio and therefore, a poorer performance of the instrument.

5.4 Temperature of key components

The temperature of the laser system and of the receiver system has an influence on the uncertainty of distance measurement. Most of these instruments have a built-in temperature compensation system to minimize this kind of influence.

5.5 Atmospheric influence

The maximum range and the accuracy of laser distance meters are influenced by meteorological conditions at the moment of the measurements being taken. These conditions include variations in air temperature, air pressure and humidity of the air. Distances calculated by handheld laser distance meters are based on predefined meteorological conditions. To achieve accurate measurements, in particular at long distances, these meteorological variables in the distance calculation shall be determined and the measured distance shall be corrected accordingly if the device under test offers this possibility.

5.6 Measurement resolution

The measurement resolution of a measurement instrument shall be at least two times better than the specified accuracy. For very accurate measurements, like in a calibration situation, a laser distance meter shall offer a unit setting which allows a measurement resolution that is at least five times better than the specified accuracy.

5.7 Average deviation and uncertainty of measurement

The typical user of handheld laser distance meters wants to take only one single measurement and wants to rely on the specified maximum tolerances. Therefore, it is the value of the combined and expanded uncertainty of a single measurement that the user wants to see below the tolerance limits.

5.8 Relevant contribution to uncertainty

Table 3 — Relevant contribution to uncertainty

Uncertainty contribution	Distribution	Type[a]
Reference system	Normal	B[b]
Measurement resolution	Rectangular	B
Absolute distance test (internal noise at typical conditions)	Normal	A
Background illumination (additional offset and noise)	Normal	A
Temperature (additional offset and noise)	Normal	A

[a] For further information, refer to GUM "Guide to the Expression of Uncertainty in Measurement".

[b] The uncertainty contribution of the "reference system" comprises a number of uncertainty contributions, including inter alia, contributions by the uncertainty of the length standard used, by the uncertainty due to an imperfect geometric alignment of reference and device under test or by the uncertainty due to imperfect temporal synchronization. All these contributions have to be carefully, individually assessed to quantify the overall uncertainty of the reference system.

5.9 Instruction for instrument specifications

As customers of handheld laser distance meters usually are not used to the term "uncertainty of measurement", the manufacturers may use the expression "measurement accuracy" in their product specification.

Since the performance of a handheld laser distance meter depends on various conditions, the specification of the product shall indicate the conditions that apply, e.g. distance dependency, target reflectivity, background illumination and temperature range. It is mandatory to indicate the performance data (accuracy and range) with favourable conditions and with unfavourable conditions.

Favourable conditions are white and diffuse reflecting target, low background illumination and temperatures about 20 °C.

Unfavourable conditions are targets with lower or higher reflectivity, high background illumination and temperatures at the upper or lower end of the specified temperature range.

For an example, see Annex A.

6 Test procedure for determining the compliance with accuracy specifications

6.1 Test concept

As mentioned before, the accuracy of handheld laser distance meters depends on various factors. The test concept of this document focuses on the main influences, such as measurement distance, temperature of instrument and background illumination.

The target reflectivity, which also can have an impact on the accuracy, is not tested directly by changing targets with different reflectivity factors. The reason is that it is quite difficult to get targets with well defined, homogeneous and stable reflectivity factors. In addition, the effect of a target with a lower reflectivity factor of 25 % can be tested using a target with 100 % reflectivity at double distance. Therefore, the effects of lower reflectivity factors are indirectly tested at the absolute distance test described in 6.4.2.

6.2 Requirements

6.2.1 General

To determine compliance with the accuracy specifications for handheld laser distance meters, the following measurement setup is used.

For examples of determining compliance with accuracy specifications, see Annex B.

6.2.2 Apparatus

6.2.2.1 Target plate, meeting the following specifications:

Size: 0,25 m × 0,25 m;

Reflectivity: (95 ± 5) % (see Annex E).

Special attention is to be paid to the effect of penetration of the laser beam into certain materials (see Annex F). In addition, specular surfaces and reflectors should be avoided along the measurement line.

6.2.2.2 Background illumination lamp, that shall achieve at least an illuminance of 30 klx on the used target plate. Check with an illuminance meter (lux meter) directed as perpendicularly as possible to the target at 0,1 m distance from the target.

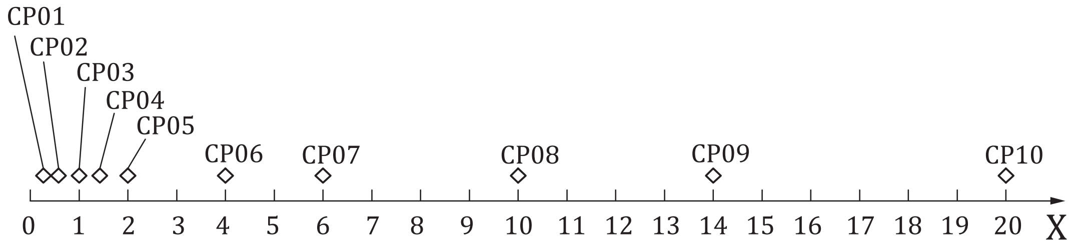
6.2.2.3 Temperature chamber, capable of heating the devices under test up to +40 °C and cooling them down to +5 °C. The measurements can be taken inside a big temperature chamber or by taking the heated (or cooled) devices out of the chamber and immediately taking the measurements on a known reference distance.

6.2.2.4 Calibrated reference distance measurement system, to determine the distance between target and device under test. The uncertainty of measurement of the reference system shall be 20 % or less than the expected uncertainty of measurement of the device under test.

6.3 Configuration of check points

Select 10 check points CP01 to CP10.

Check point CP10 shall be set either to the longest specified distance of the device under test or to the maximum range of the reference distance measurement system, but at least 10 m. The following configuration of check points takes into consideration that typical customers measure shorter distances more frequently than longer ones.



D(CP01) = 0,02 · D(CP10)

D(CP02) = 0,03 · D(CP10)

D(CP03) = 0,05 · D(CP10)

D(CP04) = 0,07 · D(CP10)

D(CP05) = 0,10 · D(CP10)

D(CP06) = 0,20 · D(CP10)

D(CP07) = 0,30 · D(CP10)

D(CP08) = 0,50 · D(CP10)

D(CP09) = 0,70 · D(CP10)

D(CP10) = max distance

X: Distance (m)

Figure 1 — Example: CP10 = 20 m

6.4 Measurement procedure

6.4.1 General

To determine compliance with accuracy specifications for handheld laser distance meters, the following procedure is recommended.

6.4.2 Absolute distance test

This test shall be performed under favourable conditions.

Target reflectivity: (95 ± 5) %;

Background illumination: <3 klx;

Temperature range: (20 ± 5) °C;

Define the check points (see 6.3).

At each check point, determine the reference distance with the reference distance measurement system and take 10 measurements with the device under test. Ensure correct alignment of the handheld laser distance meter to the target by checking at the shortest and the longest distance of the reference system that the laser spot still hits the target at the centre mark and that the target is oriented perpendicularly to the laser beam within ±1°. Due to this alignment procedure, an additional offset error might come into account which is not allowed to be compensated by a corrective value (for more details, refer to Annex G).

6.4.3 Background illumination test

This test evaluates the influence of high background illumination on the measurement result in comparison to the result of measurements at low background illumination.

Target reflectivity: (95 ± 5) %;

Background illumination, case A: <3 klx;

Background illumination, case B: >30 klx;

Temperature range: (20 ± 5) °C.

Build up the measurement setup for the background illumination test (see Annex D for an example of a possible setup). At the checkpoint CP01, CP02 or CP03 (depending on which point fits better for the test under 6.4.4), set the background illumination reflected by the measurement target to an illuminance less than 3 klx. Determine the reference distance with the reference distance measurement system and take and record 10 measurements with the device under test. In the next step, set the background illumination reflected by the measurement target to an illuminance higher than 30 klx and take and record another 10 measurements with the device under test.

6.4.4 Temperature test

This test evaluates the influence of other ambient temperatures on the measurement result in comparison to the measurement results at 20 °C.

Target reflectivity: (95 ± 5) %;

Background illumination: <3 klx;

Temperature, case A: +5 °C ± 2 °C;

Temperature, case B: +20 °C ± 2 °C;

Temperature, case C: +40 °C ± 2 °C.

Put the device under test into a temperature chamber and let the instruments adapt to the test temperature of case A (recommendation: 2 min/°C). Then, take the instrument out of the chamber and immediately take and record 10 measurements at the distance CP01, CP02 or CP03 (same distance as 6.4.3). Check that the background illumination reflected by the target is below 3 klx. Repeat the same procedure for the remaining two test cases. At test case A, verify that the receiver optics do not mist up during measurements.

Alternatively, the measurements could be taken directly inside a temperature chamber if the instrument is mounted on a reference distance measuring bar. In this case, the expansion of the reference distance measuring bar over temperature has to be compensated in the calculations.

6.5 Calculation of deviations and uncertainty of measurement

6.5.1 Absolute distance test

Calculate the deviation ΔM_i of all measurements M_i from the corresponding reference value at each check point.

$$\Delta M_i = M_i - D_{REF} \tag{1}$$

Check, if all calculated deviations ΔM_i are inside the specified tolerance field defined for favourable conditions. Assuming a level of confidence of 95 %, only 5 of the 100 measured points (10 at each check point) are allowed to lie outside the tolerance field with favourable conditions.

At each check point, calculate the experimental mean value of the absolute distance test, $\bar{D}_{AD}$:

$$\bar{D}_{AD} = \frac{1}{N} \sum_{i=1}^{N} M_i \tag{2}$$

Calculate at each check point the deviation $\Delta \bar{D}_{AD}$ of the experimental mean value from the corresponding reference value:

$$\Delta \bar{D}_{AD} = \bar{D}_{AD} - D_{REF} \tag{3}$$

At each check point, calculate the corresponding experimental standard deviation, s_{AD}, of the measured values and take it as the standard uncertainty, u_{AD}, associated with the measured values:

$$u_{AD} = s_{AD} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} \left(M_i - \bar{D}_{AD} \right)^2} \tag{4}$$

6.5.2 Background illumination test

Calculate for both cases, low background illumination BG, low < 3 klx, and high background illumination BG, high > 30 klx, and for each measurement $M_{i,X}$, the deviation $\Delta M_{i,X}$ from the reference value.

For each background illumination case, calculate the experimental mean value, $\bar{D}_{BG,X}$:

$$\bar{D}_{BG,X} = \frac{1}{N} \sum_{i=1}^{N} M_{i,X} \tag{5}$$

where X = background low, high.

Calculate the deviation $\Delta \bar{D}_{BG,X}$ of the experimental mean value from the corresponding reference value:

$$\Delta \bar{D}_{BG,X} = \bar{D}_{BG,X} - D_{BG,REF} \tag{6}$$

where X = background low, high.

