INTERNATIONAL STANDARD

ISO 16331-1

First edition
2012-05-01

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
ISO 16331-1:2012(E)

Contents

Page

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 16331-1 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

ISO 16331 consists of the following parts, under the general title *Optics and optical instruments — Laboratory procedures for testing surveying and construction instruments*:

— *Part 1: Performance of handheld laser distance meters*

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.

In comparison with ISO 17123, which specifies methods of checking compliance with the specifications by the user of the instrument without any additional measurement equipment, ISO 16331 specifies the procedures to be applied for checking compliance with the specifications by using additional laboratory equipment which the typical user does not have access to.

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

Part 1:
Performance of handheld laser distance meters

1 Scope

This part of ISO 16331 specifies procedures for checking compliance with performance specifications of handheld laser distance meters.

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, *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)*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 98-3, ISO/IEC Guide 99, ISO 3534-1 and ISO 9849 apply.

4 Symbols and abbreviated terms

Table 1 — Symbols and abbreviated terms

AD	absolute distance (as index of measurements and calculations)
Add	additional contribution (as index extension of measurements and calculations)
BG	background illumination (as index of measurements and calculations)
CP_X	check point X
D	distance
D_{REF}	reference distance
$\overline{D}$	mean value of a set of distances
$\overline{D}_{AD}$	mean value of a set of distances taken at the absolute distance test
$\overline{D}_{BG}$	mean value of a set of distances taken at the background illumination test
$\overline{D}_{T}$	mean value of a set of distances taken at the temperature test
DR	display resolution

Table 1 *(continued)*

Δ	deviation
$\Delta\overline{D}$	deviation of the mean value of a set of measured distances in relation to the reference distance
$\Delta\overline{D}_{AD}$	deviation of the mean value of a set of measured distances in relation to the reference distance at the absolute distance test
$\Delta\overline{D}_{BG,Add}$	additional deviation of the mean value of a set of measured distances at the high background illumination case in reference to the deviation of the mean value of a set of measured distances at the low background illumination case
$\Delta\overline{D}_{C,max}$	combined positive deviation of the mean value including background illumination and temperature influences
$\Delta\overline{D}_{C,min}$	combined negative deviation of the mean value including background illumination and temperature influences
$\Delta\overline{D}_{T05,Add}$	additional deviation of the mean value of a set of measured distances at the temperature test at 5 °C in reference to the deviation of the mean value at the temperature test at 25 °C
$\Delta\overline{D}_{T45,Add}$	additional deviation of the mean value of a set of measured distances at the temperature test at 45 °C in reference to the deviation of the mean value at the temperature test at 25 °C
ΔM_i	deviation of an individual distance measurement in relation to the reference system value
k	extension factor for a level of confidence of 95 %
M	Measurement value
M_i	individual measurement value
N	number of measurements taken at each check point
RT	As index for measurements and calculations at range test
s	experimental standard deviation
s_{AD}	experimental standard deviation at the absolute distance test
s_{BG}	experimental standard deviation at the background illumination test
s_T	experimental standard deviation at the temperature test
T	temperature (as index of measurements and calculations)
T05	Temperature 5 °C
T45	Temperature 45 °C
u	uncertainty of measurement
u_{AD}	uncertainty of measurement at the absolute distance test
u_{BG}	uncertainty of measurement at the background illumination test
$u_{BG,Add}$	additional uncertainty of measurement at the high background illumination case in relation to the uncertainty of measurement at the low background illumination case
u_C	combined uncertainty
u_{DR}	uncertainty due to display resolution
$u_{REF,AD}$	uncertainty of the reference system at the absolute distance test
$u_{REF,BG}$	uncertainty of the reference system at the background illumination test
$u_{REF,T}$	uncertainty of the reference system at the temperature test
u_{RT}	uncertainty of measurements at range test
u_T	uncertainty of measurement at the temperature test
$u_{T,Add}$	additional uncertainty of measurement at higher or lower temperature in relation to the uncertainty of measurement at 25 °C
U	expanded uncertainty
x	Index for individual cases

5 General information

5.1 General

The maximum measurement range on natural targets and the uncertainty of measurements provided by handheld laser distance meters are influenced by various factors.

5.2 Target reflectivity

The higher the target reflectivity, the better the signal to noise ratio at the receiver; therefore better measurement performance on natural targets 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.

5.6 Display resolution

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

5.7 Average deviation and uncertainty of measurement

Even though the calculation of average values is necessary to find out systematic deviations, the typical user of handheld laser distance meters is not willing to do so. The user rather 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 2 — Relevant contribution to uncertainty

Uncertainty contribution	Distribution	Type
Reference system	Normal	B
Display 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

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 typical error tolerances (indoor conditions) and the maximum error tolerances (outdoor conditions).

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. To avoid difficult test setups, the test concept of this International Standard 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.

6.2.2 Apparatus

6.2.2.1 Target plate, meeting the following specifications:

Size: 0,25 m x 0,25 m.

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

Orientation: perpendicular to the measurement direction.

Special attention is to be paid to the effect of penetration of the laser beam into certain materials (see Annex F).

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 perpendicularly to the target at 0,1 m distance from the target.

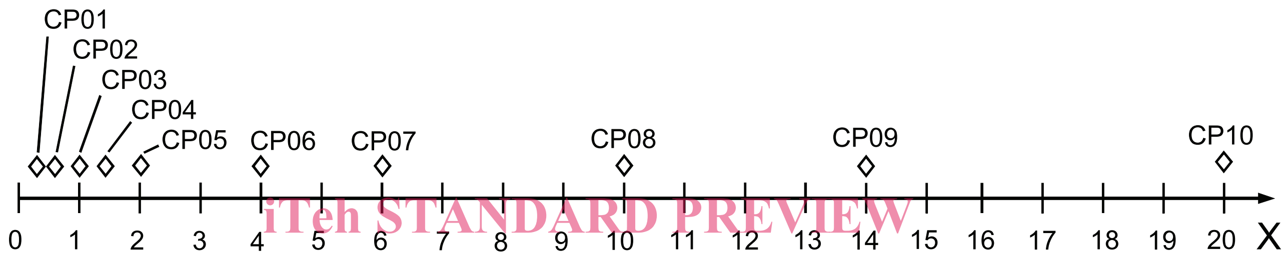
6.2.2.3 Temperature chamber, capable of heating the devices under test up to +45 °C and cooling them down to +5 °C. The measurements can be taken inside a big temperature chamber or by taking the heated (or cooled) devices out of the chamber and immediately taking the measurements on a known reference 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. 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 on natural targets for handheld laser distance meters, the following procedure is recommended.

6.4.2 Absolute distance test

Target reflectivity: 95 % ± 5 %.

Background illumination: < 3 klx (indoor conditions).

Temperature: 25 °C ± 3 °C.

Define the check points (see 6.3).

At each check point, take and record one measurement with the reference distance measurement system and 10 measurements with the device under test. Ensure that the alignment of the handheld laser distance meter to the target is correct.

6.4.3 Background illumination test

Target reflectivity: 95 % ± 5 %.

Temperature: 25 °C ± 3 °C.

Background illumination, case A: < 3 klx.

Background illumination, case B: > 30 klx.

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

Target reflectivity: 95 % ± 5 %.

Background illumination: < 3 klx.

Temperature, case A: +5 °C ± 2 °C.

Temperature, case B: +25 °C ± 2 °C.

Temperature, case C: +45 °C ± 2 °C.

NOTE If the specified temperature range of the instrument is narrower than +5 °C to +45 °C, the test temperatures for cases A to C may be adapted correspondingly (e.g. +5 °C, +20 °C, +35 °C).

Put the device under test into a temperature chamber and let the instruments adapt to the test temperature of case A. Then take the instrument out of the chamber and immediately take and record 10 measurements at the distance CP01 or CP02 or CP03 (same distance as under 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.

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 typical error tolerance field. Assuming a level of confidence of 95 % for the typical tolerance definition, only 5 of the 100 measured points (10 at each check point) are allowed to lie outside the specified typical error tolerance field.

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

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

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

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

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.

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

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 $\overline{D}_{BG,X}$.

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

where X = background low, high.

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

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

where X = background low, high.

Calculate the additional deviation $\Delta\overline{D}_{BG,Add}$ caused by the background illumination.

$$\Delta\overline{D}_{BG,Add} = \Delta\overline{D}_{BG,high} - \Delta\overline{D}_{BG,low} \tag{7}$$

Calculate the corresponding experimental standard deviations for both cases of background illumination and take them as the standard uncertainties associated with both cases.

$$u_{BG,X} = s_{BG,X} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(M_{i,X} - \overline{D}_{BG,X})^2} \tag{8}$$

where X = background low, high.

Calculate the additional uncertainty $u_{BG,Add}$ caused by the background illumination, assuming that $u_{BG,high} > u_{BG,low}$.

$$u_{BG,Add} = \sqrt{u_{BG,high}^2 - u_{BG,low}^2} \tag{9}$$

6.5.3 Temperature test

Calculate for each temperature case and for each measurement $M_{i,X}$ the deviation $\Delta M_{i,X}$ from the corresponding reference value.