INTERNATIONAL STANDARD

ISO 10360-10

Second edition
2021-08

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 10:
Laser trackers

Spécification géométrique des produits (GPS) — Essais de réception et de vérification périodique des systèmes à mesurer tridimensionnels (SMT) —

Partie 10: Laser de poursuite

Reference number
ISO 10360-10:2021(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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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 213, *Dimensional and geometrical product specifications and verification*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and verification,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 10360-10:2016), which has been technically revised.

The main changes to the previous edition are as follows:

— the number of lengths tested has been reduced;

— user-selectable positions for two-face testing have been added;

— more guidance on interim testing has been added;

— symbol E_{Uni} revised to E_{Vol}.

A list of all parts in the ISO 10360 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

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain link F of the chain of standards on size, distance, form, orientation, location and run-out.

The ISO/GPS matrix model given in ISO 14638 gives an overview of the ISO/GPS system of which this document is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated.

More detailed information on the relation of this document to other standards and the GPS matrix model can be found in Annex H.

The objective of this document is to provide a well-defined testing procedure for:

a) laser tracker manufacturers to specify performance by maximum permissible errors (MPEs); and

b) to allow testing of these specifications using calibrated and traceable test lengths, test spheres and flats.

The benefits of these tests are that the measured result has a direct traceability to the unit of length, the metre, and that it gives information on how the laser tracker will perform on similar length measurements.

This document is distinct from ISO 10360-2, which is for coordinate measuring machines (CMMs) equipped with contact probing systems, in that the orientation of the calibrated test lengths reflects the different instrument geometry and error sources within the instrument.

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 10: Laser trackers

1 Scope

This document specifies the acceptance tests for verifying the performance of a laser tracker by measuring calibrated test lengths, according to the specifications of the manufacturer. It also specifies the reverification tests that enable the user to periodically reverify the performance of the laser tracker. The acceptance and reverification tests given in this document are applicable to laser trackers utilizing a retroreflector, or a retroreflector in combination with a stylus or optical distance sensor, as a probing system. Laser trackers that use interferometric measurement (IFM), absolute distance measurement (ADM) or both can be verified using this document. This document can also be used to specify and verify the relevant performance tests of other spherical coordinate measurement systems that use cooperative targets, such as "laser radar" systems.

NOTE Systems which do not track the target, such as laser radar systems, will not be tested for probing performance.

This document does not explicitly apply to measuring systems that do not use a spherical coordinate system. However, interested parties can apply this document to such systems by mutual agreement.

This document specifies:

— performance requirements that can be assigned by the manufacturer or the user of the laser tracker;

— the manner of execution of the acceptance and reverification tests to demonstrate the stated requirements;

— rules for proving comformity;

— applications for which the acceptance and reverification tests can be used.

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 10360-8:2013, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 8: CMMs with optical distance sensors*

ISO 10360-9:2013, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 9: CMMs with multiple probing systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

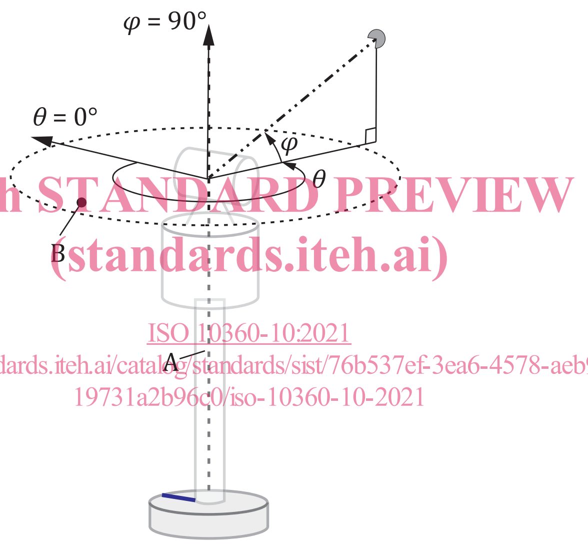
— IEC Electropedia: available at http://www.electropedia.org/

3.1
laser tracker
coordinate measuring system in which a cooperative target is followed with a laser beam and its location determined in terms of a distance (range) and two angles

Note 1 to entry: The two angles are referred to as azimuth, θ, (rotation about a vertical axis – the standing axis of the laser tracker) and either elevation, φ, (angle above a horizontal plane – perpendicular to the standing axis) or zenith (angle from the standing axis).

Note 2 to entry: Care should be used with the symbols associated with spherical coordinate systems, as different conventions exist. For example, the description of a spherical coordinate system in ISO 80000-2 uses the symbols differently and uses the zenith angle (away from vertical) rather than elevation.

Note 3 to entry: See Figure 1



Key

A standing axis

B horizontal plane (of the laser tracker)

θ azimuth angle

φ elevation angle

Figure 1 — Coordinate system of a laser tracker

3.2
interferometric measurement mode
IFM mode
measurement method that uses a laser displacement interferometer integrated in a *laser tracker* (3.1) to determine distance (range) to a target

Note 1 to entry: Displacement interferometers can only determine differences in distance, and therefore require a reference distance (e.g. home position).

3.3
absolute distance measurement mode
ADM mode
measurement method that uses time of flight instrumentation integrated in a *laser tracker* (3.1) to determine the distance (range) to a target

Note 1 to entry: Time of flight instrumentation may include a variety of modulation methods to calculate the distance to the target.

3.4
retroreflector
passive device designed to reflect light back parallel to the incident direction over a range of incident angles

Note 1 to entry: Typical retroreflectors are the cat's-eye, the cube corner and spheres of special material.

Note 2 to entry: Retroreflectors are cooperative targets.

Note 3 to entry: For certain systems, for example laser radar, the retroreflector will possibly be a cooperative target such as a polished sphere.

3.5
spherically mounted retroreflector
SMR
retroreflector (3.4) that is mounted in a spherical housing

Note 1 to entry: In the case of an open-air cube corner, the vertex is typically adjusted to be coincident with the sphere centre.

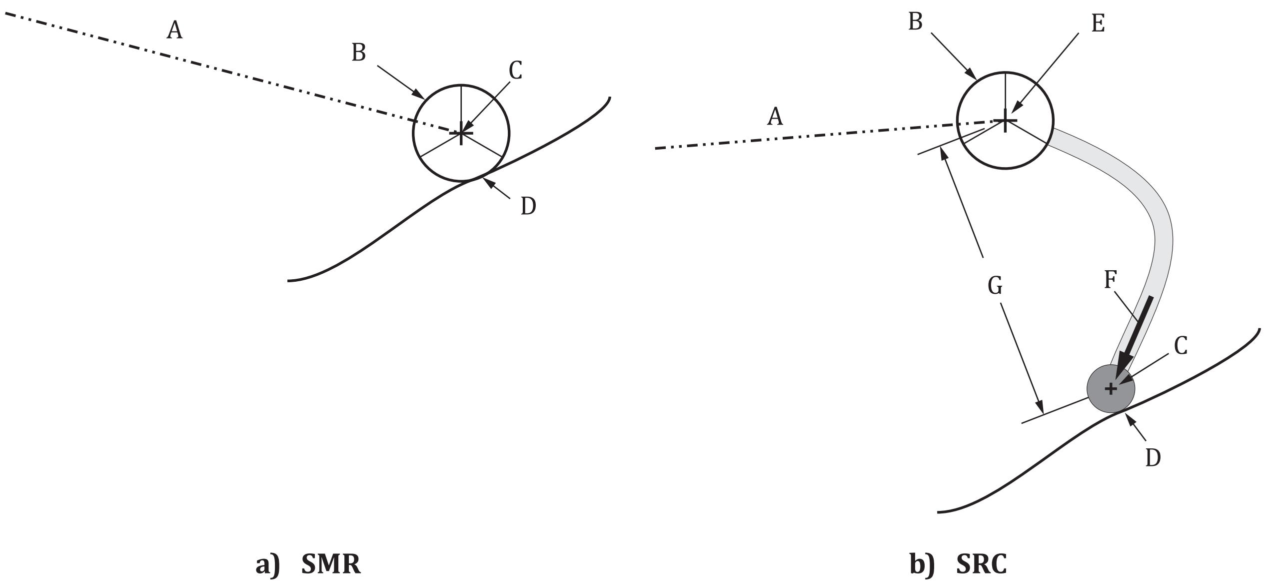
Note 2 to entry: The tests in this document are typically executed with a spherically mounted retroreflector.

Note 3 to entry: See Figure 2.

3.6
stylus and retroreflector combination
SRC
probing system that determines the measurement point utilizing a probe stylus to contact the workpiece, a *retroreflector* (3.4) to determine the base location of the probe, and other means to find the stylus orientation unit vector

Note 1 to entry: The datum for the stylus tip offset (l) is the centre of the retroreflector.

Note 2 to entry: See Figure 2.



Key

A laser beam
B retroreflector
C measurement point
D contact point
E base location
F normal probing direction vector
G stylus tip offset length *l*

Figure 2 — Representation of SMR versus SRC (simplified figures)

3.7
optical distance sensor and retroreflector combination
ODR
probing system that determines the measurement point utilizing an optical distance sensor to measure the workpiece, a *retroreflector* (3.4) to determine the base location of the optical distance sensor and other means to find the orientation of the optical distance sensor

3.8
target nest
nest
device designed to repeatably locate an *SMR* (3.5)

3.9
length measurement error
$E_{\mathrm{Vol:L:LT}}$
$E_{\mathrm{Bi:L:LT}}$
error of indication when performing an averaged ($E_{\mathrm{Vol:L:LT}}$) or bidirectional ($E_{\mathrm{Bi:L:LT}}$) point-to-point distance measurement of a calibrated test length using a laser tracker with a stylus tip offset of L

Note 1 to entry: $E_{\mathrm{Vol:0:LT}}$ and $E_{\mathrm{Bi:0:LT}}$ (used frequently in this document) correspond to the common case of no stylus tip offset, as the retroreflector optical centre is coincident with the physical centre of the probing system for *spherically mounted retroreflectors* (3.5).

3.10
normal CTE material
material with a coefficient of thermal expansion (CTE) between 8×10^{-6}/°C and 13×10^{-6}/°C

Note 1 to entry: Some documents may express CTE in units 1/K or K^{-1}, which is equivalent to 1/°C.

[SOURCE: ISO 10360-2:2009, 3.3, modified — Note 1 to entry added.]

3.11
probing form error
$P_{Form.Sph.1x25:SMR:LT}$
error of indication within which the range of Gaussian radial distances can be determined by a least-squares fit of 25 points measured by a *laser tracker* (3.1) on a spherical material standard of size

Note 1 to entry: Only one least-squares fit is performed, and each point is evaluated for its distance (radius) from this fitted centre.

3.12
probing size error
$P_{Size.Sph.1x25:SMR:LT}$
error of indication of the diameter of a spherical material standard of size as determined by a least-squares fit of 25 points measured with a *laser tracker* (3.1)

3.13
location error
two-face error
plunge and reverse error
$L_{Dia.2x1:P\&R:LT}$
distance, perpendicular to the beam path, between two measurements of a stationary *retroreflector* (3.4), where the second measurement is taken with the *laser tracker* (3.1) azimuth angle at approximately 180° from the first measurement and the laser tracker elevation angle is approximately the same

Note 1 to entry: This combination of axis rotations is known as a 'two-face' or 'plunge and reverse' test.

Note 2 to entry: The laser tracker base is fixed during this test.

3.14
maximum permissible error of length measurement
$E_{Vol:L:LT, MPE}$
$E_{Bi:L:LT, MPE}$
extreme value of the *length measurement error* (3.9), $E_{Bi:L:LT}$ or $E_{Vol:L:LT}$, permitted by specifications

Note 1 to entry: $E_{Vol:0:LT}$ and $E_{Bi:0:LT}$ (used frequently in this document) correspond to the common case of no stylus tip offset, as the retroreflector optical centre is coincident with the physical centre of the probing system for *spherically mounted retroreflectors* (3.5).

3.15
maximum permissible error of probing form
$P_{Form.Sph.1x25:SMR:LT, MPE}$
extreme value of the *probing form error* (3.11), $P_{Form.Sph.1x25:SMR:LT}$, permitted by specifications

3.16
maximum permissible error of probing size
$P_{Size.Sph.1x25:SMR:LT, MPE}$
extreme value of the *probing size error* (3.12), $P_{Size.Sph.1x25:SMR:LT}$, permitted by specifications

3.17
maximum permissible error of location
$L_{Dia.2x1:P\&R:LT, MPE}$
extreme value of the location error, $L_{Dia.2x1:P\&R:LT}$, permitted by specifications

3.18
rated operating condition
operating condition that must be fulfilled, according to specification, during measurement in order that a measuring instrument or measuring system performs as designed

Note 1 to entry: Rated operating conditions generally specify intervals of values for a quantity being measured and for any influence quantity.

Note 2 to entry: Within the ISO 10360 series, the term “as designed” in the definition means “as specified by MPEs”.

Note 3 to entry: When the rated operating conditions are not met in a test according to the ISO 10360 series, neither comformity nor non-comformity to specifications can be determined.

[SOURCE: ISO/IEC Guide 99:2007, 4.9, modified — definition revised and Notes 2 and 3 to entry added.]

4 Symbols

For the purpose of this document, the symbols in Table 1 apply.

Table 1 — Symbols of specification quantities

Symbol	Meaning
$E_{\text{Vol:L:LT}}$ $E_{\text{Bi:L:LT}}$	Length measurement error (averaged or bi-directional lengths) where L is the stylus tip offset
$P_{\text{Form.Sph.1x25:SMR:LT}}$	Probing form error
$P_{\text{Size.Sph.1x25:SMR:LT}}$	Probing size error
$L_{\text{Dia.2x1:P\&R:LT}}$	Location error (from two-face tests)
$E_{\text{Vol:L:LT,MPE}}$ $E_{\text{Bi:L:LT,MPE}}$	Maximum permissible error of length measurement where L is the stylus tip offset
$P_{\text{Form.Sph.1x25:SMR:LT,MPE}}$	Maximum permissible error of probing form
$P_{\text{Size.Sph.1x25:SMR:LT,MPE}}$	Maximum permissible error of probing size
$L_{\text{Dia.2x1:P\&R:LT,MPE}}$	Maximum permissible error of location (from two-face tests)
Accessory sensor testing – SRC	
$P_{\text{Form.Sph.1x25:SRC:LT}}$	Probing form error for SRC
$P_{\text{Size.Sph.1x25:SRC:LT}}$	Probing size error for SRC
$P_{\text{Dia.15x1:SRC:LT}}$	Orientation error for SRC
$P_{\text{Form.Sph.1x25:SRC:LT,MPE}}$	Maximum permissible error of probing form for SRC
$P_{\text{Size.Sph.1x25:SRC:LT,MPE}}$	Maximum permissible error of probing size for SRC
$P_{\text{Dia.15x1:SRC:LT,MPE}}$	Maximum permissible error of orientation for SRC
Accessory sensor testing – ODR	
$P_{\text{Form.Sph.1 × 25:ODR:LT}}$	Probing form error for ODR (25 points)
$P_{\text{Form.Sph.D95 \%:ODR:LT}}$	Probing form error for ODR (95 % of the points)
$P_{\text{Size.Sph.1 × 25:ODR:LT}}$	Probing size error for ODR (25 points)
$P_{\text{Size.Sph.All:ODR:LT}}$	Probing size error for ODR (all points)
$E_{\text{Form.Pla.D95 \%:ODR:LT}}$	Flat form error of measurement with ODR (95 % of the points)
$P_{\text{Form.Sph.1 × 25:ODR:LT,MPE}}$	Maximum permissible error of probing form for ODR (25 points)
$P_{\text{Form.Sph.D95 \%:ODR:LT,MPE}}$	Maximum permissible error of probing form for ODR (95 % of the points)
$P_{\text{Size.Sph.1 × 25:ODR:LT,MPE}}$	Maximum permissible error of probing size for ODR (25 points)
$P_{\text{Size.Sph.All:ODR:LT,MPE}}$	Maximum permissible error of probing size for ODR (all points)

Table 1 *(continued)*

Symbol	Meaning
$E_{\text{Form.Pla.D95 \%:ODR:LT,MPE}}$	Maximum permissible error of flat form measurement with ODR (95 % of the points)
Multiple sensor testing	
$P_{\text{Form.Sph.}n\text{x25::MPS.LT}}$	Multiple probing system form error
$P_{\text{Size.Sph.}n\text{x25::MPS.LT}}$	Multiple probing system size error
$L_{\text{Dia.}n \times \text{25::MPS.LT}}$	Multiple probing system location error
$P_{\text{Form.Sph.}n\text{x25::MPS.LT,MPE}}$	Maximum permissible multiple probing system form error
$P_{\text{Size.Sph.}n\text{x25::MPS.LT,MPE}}$	Maximum permissible multiple probing system size error
$L_{\text{Dia.}n \times \text{25::MPS.LT,MPE}}$	Maximum permissible multiple probing system location error

NOTE 1 For the common case of length testing with an SMR, L will be equal to 0 (e.g. $E_{\text{Bi:0:LT}}$).

NOTE 2 The specific combinations of sensors for the multiple probing system errors depend on the sensors provided with the laser tracker system. It is possible to explicitly capture the combination in the symbol, such as $P_{\text{Size.Sph.2x25:ODS,SMR:MPS.LT}}$, where the symbols indicating sensors are listed alphabetically.

NOTE 3 In the multiple sensor testing entries, n (in $n \times 25$) is the number of sensors being involved ($n \geq 2$).

5 Rated operating conditions

5.1 Environmental conditions

Limits for permissible environmental conditions such as temperature conditions, air pressure, humidity and vibration at the site of usage or testing that influence the measurements shall be specified by:

— the manufacturer, in the case of acceptance tests;

— the user, in the case of reverification tests.

In both cases, the user is free to choose the environmental conditions under which the testing will be performed within the specified limits (Form 1 in Annex A is the recommended method for specifying these conditions).

If the user wishes to have testing performed under environmental conditions other than the ambient conditions of the test site (e.g. at an elevated or lowered temperature), agreement between parties regarding who bears the cost of environmental conditioning should be attained.

5.2 Operating conditions

The conditions required by the manufacturer in order to meet the MPE specification shall be specified (e.g. as given in a specification sheet).

In addition, the laser tracker shall be operated using the procedures given in the manufacturer's operating manual when conducting the tests given in Clause 6. Specific areas in the manufacturer's manual to be adhered to include:

a) machine start-up/warm-up cycles;

b) machine compensation procedures;

c) cleaning procedures for retroreflector and nests;

d) SMR or SRC qualification;

e) location, type and number of environmental sensors (i.e. “the weather station”);

f) location, type and number of thermal workpiece sensors;

g) stability and vibration isolation of the mounting.

6 Acceptance tests and reverification tests

6.1 General

In the following:

— acceptance tests are executed according to the manufacturer's specifications and procedures that are in conformity with this document;

— reverification tests are executed according to the user's specifications and the manufacturer's procedures.

If specifications permit, the laser tracker may be tested in an orientation other than the normal upright, vertical orientation. In every case, the azimuth and elevation angles will be oriented with respect to the laser tracker. The position and orientation of the calibrated test lengths with respect to the laser tracker shall be clearly defined before the tests begin. In general, the calibrated test lengths will not rotate with the laser tracker. However, the locations for probing and two-face tests will maintain a fixed relationship with respect to the laser tracker's standing axis (i.e. they will rotate with the laser tracker). For example, if the laser tracker is mounted with its standing axis horizontal, the 'above' and 'below' directions described in Table 2 and Table 3 will be parallel to the standing axis.

Where least squares (Gaussian) fitting is used in the derivation of test results, this shall be an unconstrained fit to the data, unless constraints to the fitting are explicitly stated.

As the two-face tests can be performed quickly and will immediately reveal problems with the laser tracker geometry and its correction, it is recommended that some or all of these tests be performed first.

6.2 Probing size and form errors

6.2.1 Principle

The principle of this test procedure is to measure the size and form of a test sphere using 25 points probed with the SMR, SRC or ODR. Refer to Annex F or Annex G for additional information about testing with the SRC or ODR sensors, respectively. A least-squares sphere fit of the 25 points is examined for the errors of indication for form and size. This analysis yields the form error, $P_{\mathrm{Form.Sph.1x25:SMR:LT}}$, and the size error, $P_{\mathrm{Size.Sph.1x25:SMR:LT}}$.

NOTE 1 Probing errors $P_{\mathrm{Form.Sph.1x25:SMR:LT}}$ and $P_{\mathrm{Size.Sph.1x25:SMR:LT}}$ do not apply to laser radar systems.

NOTE 2 These are tests of the laser tracker system's ability to locate individual points in space. These tests are not intended to check any of the specifications supplied by an SMR manufacturer, although errors in the SMR will influence the test results.

NOTE 3 When performing this test with an SMR, three types of errors in the SMR can influence the results of this test. If the sphere within which the retroreflector is mounted is not a perfect sphere, this will influence the test result. Also, if the mirrored surfaces which comprise the retroreflector are not mutually orthogonal, or if their point of intersection is not coincident with the sphere centre, the test result will be affected.

6.2.2 Reference artefact

The material standard of size, i.e. the test sphere, shall have a nominal diameter not less than 10 mm and not greater than 51 mm. The test sphere shall be calibrated for size and form.

NOTE It can be difficult to make measurements on smaller test spheres due to interference with the sphere mount.

6.2.3 Procedure

Mount the test sphere so that a full hemisphere can be probed. When an SMR is used for probing, the test sphere support should be oriented away from the laser tracker. For an SRC, the support should be located away from the normal probing direction (see Figure 2).

The test sphere should be mounted rigidly to minimize errors due to bending.

Measure and record 25 points. The points shall be approximately evenly distributed over at least a hemisphere of the test sphere. Their position shall be at the discretion of the user and, if not specified, the following probing pattern is recommended (see Figure 3):

— one point on the pole of the test sphere;

— four points (equally spaced) 22,5° below the pole;

— eight points (equally spaced) 45° below the pole and rotated 22,5° relative to the previous group;

— four points (equally spaced) 67,5° below the pole and rotated 22,5° relative to the previous group;

— eight points (equally spaced) 90° below the pole (i.e. on the equator) and rotated 22,5° relative to the previous group.

NOTE Due to the manual nature of point measurement with laser trackers, it is recognized that the exact points recommended will possibly not be measured.