

**SLOVENSKI STANDARD**  
**oSIST prEN ISO 10360-11:2021**  
**01-junij-2021**

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**Specifikacija geometrijskih veličin izdelka (GPS) - Preskusi za sprejemljivost in ponovno overjanje koordinatnih merilnih strojev (KMS) - 11. del: KMS, ki uporabljajo princip rentgenske računalniške tomografije (CT) (ISO/DIS 10360-11:2021)**

Geometrical product specifications (GPS) - Acceptance and reverification tests for coordinate measuring systems (CMS) - Part 11: CMSs using the principle of X-ray computed tomography (CT) (ISO/DIS 10360-11:2021)

**iTeh STANDARD PREVIEW**

Geometrische Produktspezifikation und -prüfung (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 11: Computertomografie (ISO/DIS 10360-11:2021)

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Spécification géométrique des produits (GPS) - Essais de réception et de vérification périodique des machines à mesurer tridimensionnelles (MMTs) - Partie 11: MMTs utilisant le principe de la tomographie informatisée (CT) (ISO/DIS 10360-11:2021)

**Ta slovenski standard je istoveten z: prEN ISO 10360-11**

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17.040.30	Merila	Measuring instruments
17.040.40	Specifikacija geometrijskih veličin izdelka (GPS)	Geometrical Product Specification (GPS)

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

### Part 11: CMSs using the principle of X-ray computed tomography (CT)

*Spécification géométrique des produits (GPS) — Essais de réception et de vérification périodique des machines à mesurer tridimensionnelles (MMTs) —*

*Partie 11: MMTs utilisant le principe de la tomographie informatisée (CT)*

ICS: 17.040.30; 17.040.40

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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 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](http://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 <https://www.iso.org/patents>).

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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](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

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](http://www.iso.org/members.html).

## ISO/DIS 10360-11:2021(E)

### Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences link 5 of the chains of standards on size, distance, radius, angle, form, orientation, location, run-out and datums.

For more detailed information of the relation of this document to other standards and the GPS matrix model see [Annex I](#).

In close reliance on ISO 10360-2 and ISO 10360-5 for coordinate measuring systems (CMSs) equipped with contact probing systems as well as ISO 10360-8 for CMSs with optical distance sensors, this document specifies the acceptance and reverification tests for verifying the performance of CMSs that use the principle of X-ray computed tomography (CT). Where technically possible, the testing methodology of these parts of ISO 10360 is intended to be similar.

The metrological characteristics described in this document serve both for the specification of CMSs that use the principle of CT and for comparison between various coordinate measurement systems. This document is intentionally dedicated to CMSs that use CT where measurements are predominantly based on the attenuation contrast visible when penetrating physical matter. This document may also be applied to CMSs which use other tomographic measurement principles based on a mutual agreement.

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

## Part 11:

## CMSs using the principle of X-ray computed tomography (CT)

### 1 Scope

The purpose of this document is to define metrological characteristics and methods for testing CMSs that use the principle of CT (based on X-ray attenuation contrast) as a single sensor and which are dedicated to dimensional measurements of technical workpieces. This excludes medical imaging, medical dimensional measurements and native non-destructive (material) testing applications of CT (e.g. defect analyses). The intention of this document is to achieve – where possible – comparability with the metrological characteristics of CMSs employing tactile probes and/or optical sensors.

CMSs which use sensors other than CT are covered by this document if such sensors are used for setting up and preparing measurements for which CT is used, only.

NOTE CMSs which use other sensors together with CT to perform measurements can be specified and tested using ISO 10360-9.

This document covers CMSs which use CT as a measurement technology and which employ various hardware configurations ([Annex A](#)) and different scanning modes ([Annex B](#)). This document defines metrological characteristics and methods for testing maximum permissible errors (MPEs) that are intended specifically for non-gradient, homogeneous mono-materials, i.e. measurements of reference standards that consist of only one (relevant) material that has no relevant lateral or spatial gradient in the attenuation of X-rays.

This document does not define metrological characteristics or related testing methods that are dedicated to measuring the influence of surface roughness on CT-based CMS measurements or vice-versa (measuring roughness with CT-based CMSs).

For measuring limits of lateral structures below a certain resolution limit, [Annex E](#) mentions two types of resolution statements which the manufacturer provided as optional metrological characteristics.

This document establishes the following aspects necessary when using CT:

- Reference standards usable as alternatives to gauge blocks ([Annex C](#))
- Definition of metrological characteristics for various operating conditions
- Notes on the impact on the measurement of, for example, environmental conditions, mathematical data filters and the nature of the measurement standard's surface

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes the 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/DIS 10360-11:2021(E)**

ISO 1, *Geometrical product specifications (GPS) — Standard reference temperature for the specification of geometrical and dimensional properties*

ISO 3650, *Geometrical Product Specifications (GPS) — Length standards — Gauge blocks*

ISO 10360-1, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO 10360-2, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 2: CMMs used for measuring linear dimensions*

ISO 10360-5, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 5: Coordinate measuring machines (CMMs) using single and multiple stylus contacting probing systems using discrete point and/or scanning measuring mode*

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

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

ISO 14253-1, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for verifying conformity or nonconformity with specifications*

ISO 14253-5, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 5: Uncertainty in verification testing of indicating measuring instruments*

ISO/TS 17865, *Geometrical product specifications (GPS) — Guidelines for the evaluation of coordinate measuring machine (CMM) test uncertainty for CMMs using single and multiple stylus contacting probing systems*

ISO/TS 23165, *Geometrical product specifications (GPS) — Guidelines for the evaluation of coordinate measuring machine (CMM) test uncertainty*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

ISO/TR XXXXX, *Resolution statements for dimensional measurements of CMSs using the principle of X-ray computed tomography (CT)* (see Annex E)

**3 Terms and definitions**

For the purposes of this document, the terms and definitions given in VIM and the following 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/>

This document describes physical material measures used for the measurement of the metrological characteristics. In this document, the physical material measures are denoted as “reference measurement standards” or “reference standards” for short (see VIM). This document uses – in contrast to other standards and guidelines – the expression “artefact” only for imaging errors of the CMSs, as this meaning and expression is common in the field of CT. For probing error assessment, a calibrated sphere is used; this reference standard will be denoted as the “test sphere”. For assessing length measurement errors, various types, different reference standards may be used ([Annex C](#)). When referring to a single length assessed with a standard, the expression “test length” is used. For the readability of this document, the term “Gaussian” refers to an unweighted least-squares fit without any constraint (position or diameter, if applicable).

### 3.1 material class

**j**

Designation of material class *j*. The metrological characteristic associated with material class *j* shall be measured with a reference standard and an obstructive body – if applicable – both made from a material within the respective material class definition, *j* (*j* = Pl for class “plastic”, *j* = Al for class “aluminium”, *j* = Fe for class “steel”; see 5.6)

Note 1 to entry: An obstructive body is an uncalibrated, separate piece of material placed next to a reference standard to adjust the penetration length (see Table 2) of the material seen by X-rays in individual projections of a CT scan. 5.6 describes criteria for the material of the obstructive body and, if required, the mounting material (5.6.3).

Note 2 to entry: Occasionally, the acquisition of a complete set of X-ray projections of a single CT measurement is called a CT scan.

Note 3 to entry: *j* = Fe is deduced from chemical symbol Fe for iron, the major component of steel.

### 3.2 probing form dispersion error

$P_{\text{Form.Sph.D95\%.j::CT}}$

smallest possible width of a spherical shell which contains 95 % of all data points measured on a test sphere of *material class j* (3.1)

Note 1 to entry: The “D” inside ‘D95%’ indicated that the characteristic feature of this metrological characteristic is the “dispersion” of the population, while the “95%” inside ‘D95%’ refers to the coverage of 95 % of all points.

### 3.3 probing form error All

$P_{\text{Form.Sph.All.j::CT}}$

smallest possible width of a spherical shell which contains all data points measured on a test sphere of *material class j* (3.1)

### 3.4 probing size error All

$P_{\text{Size.Sph.All.j::CT}}$

error of indication of the (signed) difference between the diameter of a least-squares fit of all points measured on a test sphere of *material class j* (3.1) and its calibrated diameter

### 3.5 volumetric length measurement error

$E_{\text{Vol.j::CT}}$

error of indication when measuring a calibrated test length where the error is deduced from the distance between two points each determined from multiple measurement points of two respective geometrical elements on a reference standard of *material class j* (3.1)

Note 1 to entry: The absolute value of the volumetric length measurement error is in nearly all cases smaller than the bidirectional length measurement error.

### 3.6 maximum permissible probing form dispersion error

$P_{\text{Form.Sph.D95\%.j::CT,MPE}}$

MPE of  $P_{\text{Form.Sph.D95\%.j::CT}}$

### 3.7 maximum permissible probing form error All

$P_{\text{Form.Sph.All.j::CT,MPE}}$

MPE of  $P_{\text{Form.Sph.All.j::CT}}$

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## 3.8

**maximum permissible probing size error All**

$P_{\text{Size.Sph.All.j::CT,MPE}}$   
MPE of  $P_{\text{Size.Sph.All.j::CT}}$

## 3.9

**maximum permissible volumetric length measurement error**

$E_{\text{Vol.j::CT,MPE}}$   
MPE of  $E_{\text{Vol.j::CT}}$

## 3.10

**pre-knowledge**

prior knowledge according to 5.8 of the reference standard and/or the obstructive body being measured in acceptance testing that is not directly acquired by the CMS under test but could affect the points measured of the reference standard

Note 1 to entry: Examples of pre-knowledge include nominal chemical composition and CAD-related information such as nominal geometry, nominal surface normal vectors, material information and nominal dimensions.

Note 2 to entry: Metrological characteristics and respective MPE values which are assessed or specified with the use of pre-knowledge receive a test qualifier, 'PreK' or 'CAD', after the first colon.

Note 3 to entry: In case that there are other test qualifiers to be inserted, the test qualifiers 'PreK' or 'CAD' shall be the first after the colon.

Note 4 to entry: The 'CAD' test qualifier indicates pre-knowledge restricted to only CAD-related information – without any specific material designation or chemical composition knowledge. The qualifier PreK allows CAD-related information and more, making CAD-related information a subset of PreK information.

Note 5 to entry: Examples of metrological characteristics where the explicit use of pre-knowledge is indicated by a 'PreK' test qualifier are  $P_{\text{Form.Sph.D95%.j::PreK:CT}}$  and  $E_{\text{Bi.j::PreK:CT}}$  with respective MPE values  $P_{\text{Form.Sph.D95%.j::PreK:CT,MPE}}$  and  $E_{\text{Bi.j::PreK:CT,MPE}}$ . The use of a 'CAD' qualifier is similar.

Note 6 to entry: The auxiliary quantity  $E_{\text{Bi.shrt.j::PreK:CT}}$  may contain also a 'PreK' (or similarly 'CAD') test qualifier. However, there is no attributed MPE value for this quantity.

## 4 Symbols and abbreviated terms

For the purposes of the main part of this document, the symbols in [Table 1](#) and [Table 2](#) apply.

NOTE [Table D.1](#) contains symbols of optional metrological characteristics and auxiliary quantities used in the Annexes of this document.

**Table 1 — Symbols of mandatory metrological characteristics**

Symbol	Name	References in this document
$P_{\text{Form.Sph.D95%.j::CT}}$	probing form dispersion error	<a href="#">3.2</a> , <a href="#">3.6</a> , <a href="#">5.1</a> , <a href="#">6.2</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a> , <a href="#">9</a> , Annex <a href="#">D.3.4.4.3</a> , <a href="#">Annex H</a>
$P_{\text{Form.Sph.All.j::CT}}$	probing form error All	<a href="#">3.3</a> , <a href="#">3.7</a> , <a href="#">5.1</a> , <a href="#">6.2.1</a> , <a href="#">6.2.3.1</a> , <a href="#">6.2.3.3</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a> , Annex <a href="#">D.3.3.3</a> , <a href="#">Annex H</a>
$P_{\text{Size.Sph.All.j::CT}}$	probing size error All	<a href="#">3.4</a> , <a href="#">3.8</a> , <a href="#">5.1</a> , <a href="#">6.2</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a> , Annex <a href="#">D.3.4.4.3</a> , <a href="#">Annex H</a>

Table 1 (continued)

Symbol	Name	References in this document
$E_{Vol,j::CT}$	volumetric length measurement error	<a href="#">3.5</a> , <a href="#">3.9</a> , <a href="#">5.1</a> , <a href="#">6.3</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a> , Annex <a href="#">D.1</a> , Annex <a href="#">D.3.4.1</a> , Annex <a href="#">D.3.4.4.2</a> , Annex <a href="#">E.1</a> , Annex <a href="#">E.2</a>
$P_{Form.Sph.D95\%,j::CT,MPE}$	maximum permissible probing form dispersion error	<a href="#">3.6</a> , <a href="#">5.1</a> , <a href="#">6.2.4</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a> , 9
$P_{Form.Sph.All,j::CT,MPE}$	maximum permissible probing form error All	<a href="#">3.7</a> , <a href="#">5.1</a> , <a href="#">6.2.4</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a>
$P_{Size.Sph.All,j::CT,MPE}$	maximum permissible probing size error All	<a href="#">3.8</a> , <a href="#">5.1</a> , <a href="#">6.2.4</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a>
$E_{Vol,j::CT,MPE}$	maximum permissible volumetric length measurement error	<a href="#">3.9</a> , <a href="#">6.3.4</a> , <a href="#">7.1</a> , <a href="#">7.2</a> , <a href="#">7.3.3</a> , Annex <a href="#">E.1</a>

Table 2 — Symbols of auxiliary quantities

Symbol	Name (with annotation) & note(s)	References in this document
$V$	measurement volume Note 1 to entry: The measurement volume is often a cylinder, but not always. Often CMSs feature a cylindrical measurement volume where height and diameter of the cylinder are equal, but there exist also CMSs which use X-ray detectors with different height and diameter. For these CMSs the height and diameter of the cylindrical measurement volume is different.	<a href="#">5.1</a> , <a href="#">6.1.2</a>
$V_1$	minimum measurement volume (specified with MPES) Note 1 to entry: Measurement volume $V_1$ corresponds to geometrical magnification $M_1$ .	<a href="#">5.1</a> , <a href="#">6.1.2</a> , Annex <a href="#">H</a>
$V_2$	maximum measurement volume (specified with MPES) Note 1 to entry: Measurement volume $V_2$ corresponds to geometrical magnification $M_2$ .	<a href="#">5.1</a> , <a href="#">6.1.2</a> , Annex <a href="#">H</a>

Table 2 (continued)

Symbol	Name (with annotation) & note(s)	References in this document
$L_p$	<p>Maximum penetration length through the reference standard, obstructive body (if applicable) and any auxiliary material (if present) when collecting projection images of a single CT scan.</p> <p>Note 1 to entry: The "penetration length" is the individual path length of any X-ray through any matter (in a way similar to that described for <math>L_p</math>), i.e. through the reference standard, obstructive body (if applicable) and any auxiliary material (base mount, temperature sensors, cables, etc. ; if present), when collecting projection images of a single CT scan. The penetration length is counted (i.e. summed) for rays having a line trajectory from the X-ray source to a specific detector pixel. The penetration length is different for any pixel of the detector and also varies with rotation angle for each projection of a single CT scan. All penetration lengths are smaller than or equal to <math>L_p</math>. The minimum penetration length is usually nearly zero (for rays passing through air only; such rays are always present for standard CT scanning).</p> <p>Note 2 to entry: If different materials allowed for testing are penetrated (i.e. materials of material class j and respective substitute materials of material class j), the lengths penetrated in each material are added to obtain <math>L_p</math>.</p> <p>Note 3 to entry: If "other materials" (i.e. auxiliary materials) than those mentioned in the previous note are penetrated, for each material length penetrated through this material a comparable length of a material from material class j must be attributed. A comparable length from a material from material class j creates the same absorption as the "other material" being penetrated. Lengths according to Note 2 to entry; and according to Note 3 to entry; are added to obtain <math>L_p</math>.</p> <p>Note 4 to entry: It is against the intention of the acceptance test to let the lengths according to Note 3 to entry; make a significant contribution to <math>L_p</math>.</p>	<p><a href="#">5.1</a>, <a href="#">5.6.3</a>, <a href="#">6.1.2</a>, Annex <a href="#">D.3.4.4.2</a></p>
$L_{p,max}(j)$	<p>Manufacturer-specified maximum for <math>L_p</math> (as a rated operating condition) for measuring reference standards made from material class j; material identification is given in brackets.</p> <p>The statement of <math>L_{p,max}(j)</math> shall be made together with respective X-ray parameters (e.g. X-ray tube voltage, X-ray tube power, prefilter material and thickness and exposure time) and measurement parameters.</p> <p>Note 1 to entry: <math>L_{p,max}(j)</math> is an attribute to all metrological characteristics, i.e. length measurement errors, probing errors, resolution statements.</p> <p>Note 2 to entry: <math>L_{p,max}(j)</math> depends on the selected measurement parameters.</p> <p>Note 3 to entry: Providing <math>L_{p,max}(j)</math> together with respective X-ray parameters and respective measurement parameters should enable the user to measure a workpiece with a maximum penetration length of <math>L_{p,max}(j)</math> from a given material.</p> <p>Note 4 to entry: <math>L_{p,max}(j)</math> can have different values for different measurement volumes.</p>	<p><a href="#">5.1</a>, <a href="#">6.1.2</a>, <a href="#">6.2.2.1</a>, <a href="#">6.3.3.1</a>, Annex <a href="#">D.3.4.3</a>, Annex <a href="#">D.3.4.4.2</a>, Annex <a href="#">D.3.4.4.3</a>, <a href="#">Annex H</a></p>
$\tau$	Single CT scan projection measurement time (time to assess all projections for acceptance testing of a single CT scan)	<a href="#">5.5</a>
$\tau_{min}$	Minimum value of $\tau$ (as specified by the manufacturer)	<a href="#">5.5</a> , <a href="#">Annex H</a>
$\tau_{max}$	Maximum value of $\tau$ (as specified by the manufacturer)	<a href="#">5.5</a> , <a href="#">Annex H</a>

## Symbols for metrological characteristics assessed with explicit pre-knowledge

Metrological Characteristics of types as explained above, which have been assessed with explicit pre-knowledge (see 5.8) receive the test qualifier 'PreK' or 'CAD' after the first colon.

NOTE The same test qualifier 'PreK' or 'CAD' can also be used for optional metrological characteristics described in Annex D.

### Abbreviated terms

CAD	computer-aided design
CMS	coordinate measuring systems (plural CMSs)
CT	X-ray computed tomography
CTE	linear coefficient of thermal expansion
GPS	geometrical product specification(s)
MPE	maximum permissible error (plural MPEs), see VIM
VIM	International Vocabulary of Metrology (see 2)

## 5 Requirements for metrological characteristics

### 5.1 Specification requirements

It is the manufacturer's responsibility to provide a detailed specification of the MPE values of the metrological characteristics over all rated conditions for all specified hardware configurations (Annex A) and for all specified scanning modes (Annex B). The full specification also covers the requirements mentioned in 5.2 – 5.8. The manufacturer specifies the MPEs of the metrological characteristics in such a way that they are maintained throughout the entire measurement volume and under all rated measurement and operating conditions. To this end, the manufacturer shall describe the shape of the measurement volume, (e.g. diameter and height). The specification of the measurement volumes shall fully describe the unique configuration of the system geometry (e.g. the object and detector positions relative to the source). When declaring MPEs, the manufacturer shall also state relevant conditions, e.g., the maximum penetration length  $L_{p,max}$ .

This document considers two types of metrological characteristics: (1) those assessed without pre-knowledge and (2) those assessed with pre-knowledge (indicated by the 'PreK' or 'CAD' test qualifier). The differences between the cases are covered in 5.8. The actual measurement process is the same in both cases; hence, for the sake of brevity, only the case without pre-knowledge is described in 6, 7, 8 and all Annexes.

This document requires that the performance of a CT-based CMS be specified using all, not a subset, of the mandatory metrological characteristics (see 6.1). Thus, a set of all mandatory metrological characteristics can be specified either with pre-knowledge (indicated by the 'PreK' test qualifier for all of them or the 'CAD' test qualifier for all of them) or without pre-knowledge. It is also possible to specify more than one complete sets of mandatory specifications covering both cases (with and without pre-knowledge). The mandatory specifications can be supplemented with optional specifications (see Table D.1 and Annex D).

The values of the MPEs for any metrological characteristics may be stated by the manufacturer as a function of the measured length  $L$  – if applicable – and of the total penetrated length through matter  $L_p$ . In all cases, the specification shall be complied with across the CMS's entire measurement range and under all rated measurement and operating conditions. If the specification is provided by means