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Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment

Spécification géométrique des produits (GPS) — Concepts et exigences généraux pour les équipements de mesure GPS

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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 14978 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

Introduction

This International Standard is a geometrical product specification (GPS) standard and is to be regarded as a global GPS standard (see ISO/TR 14638). It influences chain links 5 and 6 of all chains of standards in the general GPS matrix.

For more detailed information of the relation of this International Standard to other standards and the GPS matrix model, see Annex C.

This International Standard contains guidance for writing the standards for specific measuring equipment.

This International Standard is intended to give the user a basic understanding of the use of ISO standards for GPS measuring equipment. This International Standard presents and defines general concepts to be used in connection with GPS measuring equipment to avoid multiple repetitions in the ISO standards for specific GPS measuring equipment. This International Standard is also intended as guidance for the manufacturer to evaluate and present specifications for characteristics for GPS measurement equipment.

This International Standard should be close at hand when reading and using ISO standards for a specific GPS measuring equipment.

Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment

1 Scope

This International Standard specifies the general requirements, terms and definitions of characteristics of simple GPS measuring equipment, e.g. micrometers, dial gauges, callipers, surface plates, height gauges, gauge blocks, but not necessarily excluding more complicated equipment. It forms the basis for standards defining and describing the design characteristics and metrological characteristics for measuring equipment. It also gives guidance for the development and content of standards for GPS measuring equipment.

This International Standard is intended to ease the communication between manufacturer/supplier and customer/user and to make the specification phase of GPS measuring equipment more accurate. This International Standard is also intended as a tool to be used in companies in the process of defining and selecting relevant characteristics for measuring equipment to be used in the quality assurance of measuring processes, i.e. in calibration and in workpiece measurements.

This International Standard also includes terms which are frequently used in connection with the characterization of specific measuring equipment.

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 1:2002, *Geometrical Product Specifications (GPS) — Standard reference temperature for geometrical product specification and verification*

ISO 1101:2004, *Geometrical Product Specifications (GPS — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 5459:—[1]), *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Datums and datum systems*

ISO 14253-1:1998, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specifications*

ISO/TS 14253-2:1999, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and product verification*

ISO/TS 17450-2, *Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators and uncertainties*

International vocabulary of basic and general terms in metrology (VIM), BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, 1987

1) To be published. (Revision of ISO 5459:1981.)

International vocabulary of basic and general terms in metrology (VIM), BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, 1993

Guide to the expression of uncertainty in measurement (GUM), BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1993[2)]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14253-1, ISO/TS 14253-2, ISO/TS 17450-2, VIM and GUM and the following apply.

3.1
measuring equipment
ME
any instrument, measurement standard, reference material and/or auxiliary apparatus or any combination thereof necessary to implement a measurement process for carrying out a specified and defined measurement

NOTE 1 This definition is necessarily wider than that of a measuring instrument [VIM:1993, 4.1] since it includes all the means necessary for producing a measurement result.

NOTE 2 The concept measuring equipment includes, for example, **indicating measuring instruments** (3.2) and **material measures** (3.3).

3.2
indicating measuring instrument
measuring equipment that displays an indication

NOTE 1 The display can be analog (continuous or discontinuous) or digital.

NOTE 2 Values of more than one quantity can be displayed simultaneously.

NOTE 3 A displaying measuring instrument can also provide a record.

[VIM:1993, 4.6]

EXAMPLES

a) Analog mechanical dial gauge,

b) digital calliper,

c) micrometer.

NOTE 4 The examples given in VIM are changed here to examples in length units.

3.3
material measure
device intended to reproduce or supply, in a permanent manner during its use, one or more known values of a given quantity

NOTE 1 The quantity concerned can be called the supplied quantity.

[VIM:1993, 4.2]

2) Corrected and reprinted in 1995.

EXAMPLES

a) Gauge block,

b) ball plate,

c) angle block,

d) limit gauge (e.g. gap gauge),

e) functional gauge,

f) surface texture standard,

g) reference ring,

h) tape measure.

NOTE 2 Material measure is included in the concept measuring equipment.

NOTE 3 The examples given in VIM are changed here to examples in length units.

3.4
mono-characteristic measuring equipment
measuring equipment which can be characterised by a single metrological characteristic

NOTE 1 Mono-characteristic measuring equipment is a simplifying theoretical concept which is described in this standard as a contrast to the case of actual multi-characteristic measuring equipment.

NOTE 2 For simplification, especially when evaluating uncertainty contributions, **multi-characteristic measuring equipment** (3.5) can be considered as a "black box" and therefore can be assumed to be a mono-characteristic measuring equipment.

3.5
multi-characteristic measuring equipment
measuring equipment which is characterised by two or more metrological characteristics

NOTE All GPS measuring equipment is multi-characteristic (see 3.4 NOTE 2).

3.6
measurement process
set of interrelated resources, activities and influences which produce a measurement

NOTE 1 This term is commonly used for the calibration of measuring equipment and the measurement of workpieces.

NOTE 2 Resources can be human or material.

3.7
intended use
⟨measuring equipment⟩ measurement process in which specific measuring equipment is to be used

NOTE 1 Knowledge about intended use usually reduces the number of metrological requirements to be calibrated.

NOTE 2 Knowledge about intended use of the maximum permissible errors (MPE, see 3.21) for the metrological requirements that need to be calibrated usually allows adjustment to more economical and less restrictive values.

3.8
calibration
⟨measuring equipment⟩ set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards

NOTE 1 The result of a calibration permits either the assignment of values of measurands to the indications, or the determination of corrections with respect to indications.

NOTE 2 A calibration can also determine other metrological properties, such as the effect of influence quantities.

NOTE 3 The result of a calibration can be recorded in a document, sometimes called a calibration certificate or a calibration report.

[VIM:1993, 6.11]

NOTE 4 The VIM definition of calibration only applies to mono-metrological characteristic measuring equipment and therefore usually does not apply to GPS measuring equipment (see 3.4 and 3.5).

3.9
calibration of a metrological characteristic
set of operations that establish, under specified conditions, the relationship between values of quantities of a metrological characteristic, and the corresponding values realized by standards

NOTE Metrological characteristics can be defined and calibrated as quantities that need mathematical or geometrical transformations to be compatible with the measurement result of the measuring equipment, e.g. flatness and parallelism of the measuring faces of an external micrometer.

3.10
global calibration
⟨measuring equipment⟩ calibration of all metrological characteristics for measuring equipment

NOTE 1 Global calibration can be used if the intended use of the equipment is not known at the time of calibration, or as an acceptance test to verify the agreed specifications in connection with the delivery of new measuring equipment.

NOTE 2 In cases of daily operation of the metrology system in a company, global calibration is usually not needed (see 3.11).

3.11
task-related calibration
⟨measuring equipment⟩ calibration of only those metrological characteristics which influence the measurement uncertainty for the intended use

NOTE 1 Usually a task-related calibration will include the calibration of only those metrological characteristics that have a major influence on the measurement uncertainty for the intended use.

NOTE 2 Task-related calibrations can be performed using other, more economical procedures than those used in global calibration; and a task-related calibration can be designed to deliver information (values and conditions) optimised for use in the specific uncertainty budget.

NOTE 3 This definition of task-related calibration is intentionally formulated differently from that in ISO 12179, but the meaning is the same. The difference in the text indicates a development in the GPS field.

3.12
metrological characteristic
MC
⟨measuring equipment⟩ characteristic of measuring equipment, which may influence the results of measurement

NOTE 1 The influence on the results of measurement is an immediate (short-term) uncertainty contribution (see Clause 6).

NOTE 2 A metrological characteristic is expressed in numerical values and can be evaluated in a unit other than that of the measurement result of the actual measuring equipment.

NOTE 3 Measuring equipment usually has several metrological characteristics.

NOTE 4 Metrological characteristics can be subject to calibration (see 3.10 and 3.11).

3.13
design characteristic
DC
⟨measuring equipment⟩ characteristic of measuring equipment which does not influence the measurement directly, but which may be of interest for other reasons when the measuring equipment is used

NOTE 1 Design characteristics can influence interchangeability, readability of line scales and digital read-outs, wear resistance, etc. (see Clause 5).

NOTE 2 Some design characteristics can influence the equipment's long-term capacity to make measurements (influencing design characteristics), e.g. its wear resistance, its environmental resistance, etc. Other design characteristics have no influence the measurements (non-influencing design characteristics).

3.14
metrological requirement
MR
⟨measuring equipment⟩ requirement for a metrological characteristic

NOTE 1 Metrological requirements can be derived from specified requirements for a product/feature to be measured, or can be decided on a general basis.

NOTE 2 A metrological requirement can be presented as a maximum permissible error (MPE, see 3.21) or as permissible limits (MPL, see 3.20).

NOTE 3 Measuring equipment usually has several metrological requirements, one for each metrological characteristic.

3.15
design requirement
DR
⟨measuring equipment⟩ requirement for a design characteristic

NOTE 1 Design requirements can be derived from the intended use of the measuring equipment or decided on a general basis, and can be given in a standard.

NOTE 2 A design requirement can be given in the form of dimensions, material requirements, interface protocols, etc. (see Clause 5).

3.16
error (of indication)
⟨measuring equipment⟩ indication of measuring equipment minus a true value of the corresponding input quantity

NOTE 1 Since a true value cannot be determined, in practice a conventional true value is used (see VIM:1993, 1.19 and 1.20).

NOTE 2 This concept applies mainly where the instrument is compared to a reference standard.

NOTE 3 For a material measure, the indication is the value assigned to it.

[VIM:1993, 5.20]

NOTE 4 The VIM term and definition generally do not apply to set-up specifications for GPS measuring equipment and certainly not to the concept of a metrological characteristic in multi-characteristic measuring equipment. Term 3.18 is used instead.

3.17
value of the actual metrological characteristic
value found by calibration and characterising the metrological characteristic

3.18
error (deviation value) of a metrological characteristic
error value characterising the actual metrological characteristic (actual value minus ideal value of the characteristic)

NOTE 1 An error of a metrological characteristic can be evaluated in a unit other than that of the measurement result of the actual measuring equipment.

NOTE 2 This term is used for multi-characteristic measuring equipment (see 3.16, NOTE 4).

3.19
maximum permissible errors
⟨measuring equipment⟩ extreme values of an error permitted by specifications, regulations, etc. for a given piece of measuring equipment

See 7.5 and Figures 9 to 12.

NOTE 1 This definition is a parallel to VIM:1993, 5.21 for measuring instruments.

NOTE 2 This term is only applicable to mono-metrological characteristic measuring equipment.

NOTE 3 This term and definition generally do not apply to specifications for GPS measuring equipment and certainly not to the concept of a metrological characteristic in multi-characteristic measuring equipment. Term 3.20 or 3.21 is used instead.

3.20
permissible limits of a metrological characteristic
MPL
extreme values of a metrological characteristic permitted by specifications, regulations, etc. for a given piece of measuring equipment

See 7.5.5 and Figure 12.

NOTE MPL can be a value or set of values or a function (MPL-function).

3.21
maximum permissible errors for a metrological characteristic
MPE
extreme values of an error of a metrological characteristic permitted by specifications, regulations, etc. for a given piece of measuring equipment

See 7.5 and Figures 9 to 12.

NOTE 1 This definition is a parallel to VIM:1993, 5.21 for measuring instruments (see 3.19).

NOTE 2 MPE can be a value or set of values or a function (MPE-function).

3.22
repeatability
⟨measuring instrument⟩ ability of a measuring instrument to provide very similar indications for repeated applications of the same measurand under the same conditions of measurement

NOTE 1 These conditions include:

— reduction to a minimum of the variations due to the observer,

— the same measurement procedure,

— the same observer,

— the same measuring equipment, used under the same conditions,

— the same location,

— repetition over a short period of time.

NOTE 2 Repeatability can be expressed quantitatively in terms of the dispersion characteristics of the indications.

[VIM:1993, 5.27]

NOTE 3 This term and definition generally do not apply to specifications for GPS measuring equipment and certainly not to the concept of a metrological characteristic in a multi-characteristic measuring equipment. Term 3.23 is used instead.

3.23
repeatability of a metrological characteristic
ability of measuring equipment to provide very similar values for repeated measurements of a particular metrological characteristic under the same conditions

NOTE 1 This definition is parallel to 3.22 for the total measurement equipment.

NOTE 2 Repeatability can be expressed quantitatively in terms of the dispersion characteristics of the indications.

3.24
hysteresis
property of measuring equipment, or a characteristic whereby the indication of the equipment or value of the characteristic depends on the orientation of the preceding stimuli

NOTE Hysteresis can also depend, for example, on the distance travelled after the orientation of stimuli has changed.

3.25
discrimination (threshold)
largest change in a stimulus that produces no detectable change in the response of a measuring instrument, the change in the stimulus taking place slowly and monotonically

NOTE The discrimination threshold can depend, for example, on noise (internal or external) or friction. It can also depend on the value of the stimulus.

[VIM:1993, 5.11]

3.26
resolution (of a displaying device)
smallest difference between indications of a displaying device that can be distinguished meaningfully

NOTE 1 This concept also applies to a recording device.

[VIM:1993, 5.12]

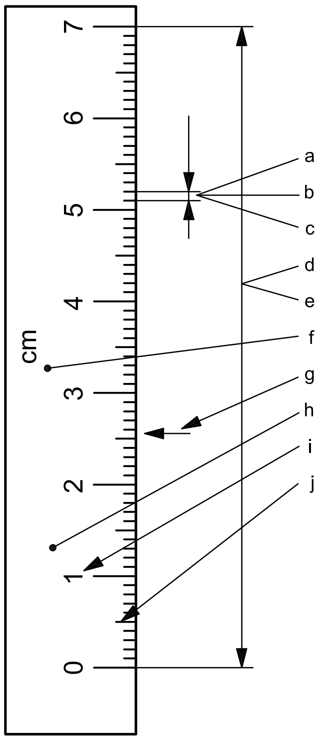
NOTE 2 See 6.3.2.3.

NOTE 3 For a digital displaying device, the resolution is equal to the digital step.

3.27
digital step
in a digital displaying device, the smallest possible change in the least significant digit

3.28
analogue scale
See Figures 1 and 2.

NOTE For detailed definitions of 3.28.1 to 3.28.10, see VIM:1993, 4.16, 4.18, 4.19, 4.20, 4.21, 4.22, 4.28 and VIM:1987, 4.17.



Key

a **scale division** (3.28.1)

b **scale interval** (3.28.2)**:** in this example, 0,1 cm for the minor scale marks or 1 cm for the major scale marks

c **scale spacing:** in this example, 0,1 cm for the minor scale marks or 1 cm for the major scale marks

d **scale length:** in this example, 7 cm

e **scale range:** in this example, 0 to 7 cm
scale span: in this example, 7 cm

f units marked on the scale (in this example, cm)

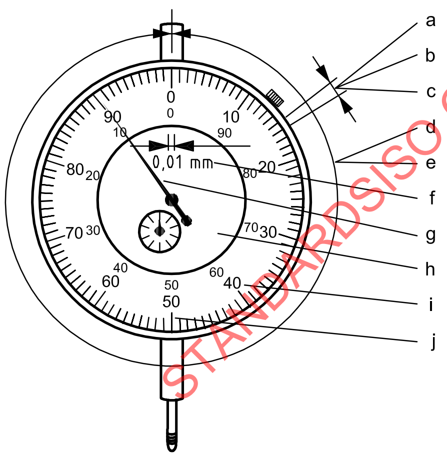
g **index**

h **face dial**

i **scale numbering:** in this example 0, 1,…,7

j **scale mark**

Figure 1 — Terms related to an analogue straight scale



Key

a **scale division** (3.28.1)

b **scale interval** (3.28.2)**:** in this example, 0,01 mm for the minor scale marks or 0,1 mm for the major scale marks

c **scale spacing:** in this example, 1 mm for the minor scale marks or 10 mm for the major scale marks

d **scale length:** in this example, approximately 100 mm

e **scale range:** in this example, 0,00 to 1,00 mm
scale span: in this example, 1 mm

f units marked on the scale (in this example, 0,01 mm)

g **index**

h **face dial**

i **scale numbering:** in this example there are two sets of scale numbering

j **scale mark**

Figure 2 — Terms related to an analogue circular scale

3.28.1
scale division
part of a scale between any two successive scale marks

[VIM:1993, 4.20]

NOTE i.e. the space between two successive scale marks

3.28.2
scale interval
distance between the values corresponding to two successive scale marks, in the units marked on the scale

NOTE Adapted from VIM:1993, 4.22

3.28.3
scale spacing
distance between two successive scale marks

NOTE 1 Adapted from VIM:1993, 4.21

NOTE 2 i.e. the physical distance between two successive scale marks

3.28.4
scale length
⟨analog straight scale⟩ physical length between the first and the last scale marks

NOTE Adapted from VIM:1993, 4.18.

3.28.5
scale length
⟨analog circular scale⟩ physical length of the circle passing through the centres of all the shortest scale marks

NOTE Adapted from VIM:1993, 4.18

3.28.6
scale range
set of values bounded by the extreme indications

NOTE 1 The lower limit of the scale range is not necessarily zero, e.g. in the case of an internal micrometer whose scale range starts at 5 mm.

NOTE 2 Adapted from VIM:1993, 4.19

3.28.7
scale span
modulus of the difference between the two limits of a scale range (see also 3.37)

3.28.8
index
pointer

NOTE Adapted from VIM:1993, 4.16

3.28.9
face dial
physical part (surface) which carries the scale

NOTE Adapted from VIM:1993, 4.27

3.28.10
scale numbering
ordered set of numbers associated with the scale marks

[VIM:1993, 4.28]

3.28.11
scale mark
lines on the face dial

NOTE Adapted from VIM:1987, 4.17 and from VIM:1993, 4.17

3.29
fixed zero
fixed reference point of indication or value (of a metrological characteristic of measuring equipment), where the error of the characteristic is zero

3.30
floating zero
floating reference point of indication or value (of a metrological characteristic of measuring equipment), where the error of the characteristic is zero

3.31
fixed zero error or value
indication or value error referenced to a fixed zero (of a metrological characteristic of measuring equipment)

3.32
floating zero error or value
indication or value error referenced to a floating zero (of a metrological characteristic of measuring equipment)

3.33
reference point
setting point for indication error evaluation in the range of measuring equipment

3.34
nominal range
range of indications obtainable with a particular setting of the controls of a measuring instrument

[VIM:1993, 5.1]

See Figure 3.

NOTE 1 Nominal range is normally stated in terms of its lower and upper limits, e.g. "24,5 mm to 50,6 mm". Where the lower limit is zero, the nominal range is commonly stated solely in terms of its upper limit.

NOTE 2 The examples given in VIM are changed in Figure 3 to examples in length units.

3.35
nominal span
modulus of the difference between the two limits of a nominal range

NOTE 1 In some fields of knowledge, the difference between the greatest and smallest values is called **range**.

See Figure 3.

NOTE 2 Adapted from VIM:1993, 5.2. The word “nominal” is added here to distinguish “nominal span” from the three other types of span (see 3.37, 3.39 and 3.41)

NOTE 3 The example given in VIM is changed in Figure 3 to an example in length units.

EXAMPLE For a nominal range of 24,5 mm to 50,6 mm, the nominal span is 26,1 mm.

3.36
measuring range
set of values of measurands for which the error of a measuring instrument is intended to lie within specified limits

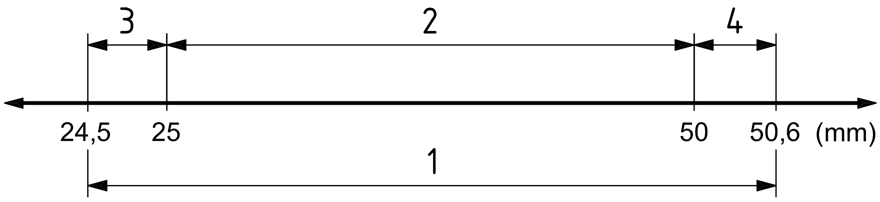
NOTE 1 Error is determined in relation to a conventional true value.

[VIM:1993, 5.4]

See Figure 3.

NOTE 2 The example given in Figure 3 is in length units.

NOTE 3 Specified limits can be given as a set of MPEs or MPLs.



Key

1 **nominal range** (3.34): 24,5 mm to 50,6 mm

nominal span (3.35): 26,1 mm (50,6 mm – 24,5 mm = 26,1 mm)

2 **measuring range** (3.36): 25 mm to 50 mm

measuring span (3.37): 25 mm (50 mm – 25 mm = 25 mm)

3 **pre-range** (3.38): 24,5 mm to 25 mm

pre-span (3.39): 0,5 mm (25 mm – 24,5 mm = 0,5 mm)

4 **post-range** (3.40): 50 mm to 50,6 mm

post-span (3.41): 0,6 mm (50,6 mm – 50 mm = 0,6 mm)

NOTE A 25mm – 50 mm external micrometer has been used as an example.

Figure 3 — Range and span terms

3.37
measuring span
modulus of the difference between the two limits of a measuring range

[VIM:1993, 5.2]

See Figure 3.

NOTE The example given in VIM is changed in this standard to an example in length units.

3.38
pre-range
range of indications obtainable with a particular setting of a measuring instrument from the lowest possible indication to the lower limit of the measuring range

See Figure 3.

NOTE The example given in Figure 3 is in length units.

3.39
pre-span
modulus of the difference between the two limits of a pre-range

See Figure 3.

NOTE The example given in Figure 3 is in length units.

3.40
post-range
range of indications obtainable with a particular setting of a measuring instrument from the upper limit of the measuring range to the highest possible indication

See Figure 3.

NOTE The example given in Figure 3 is in length units.

3.41
post-span
modulus of the difference between the two limits of a post-range

See Figure 3.

NOTE The example given in Figure 3 is in length units.

3.42
serialised identification
unique alphanumeric identification used to identify the individual measuring equipment or part of measuring equipment

NOTE 1 Manufacturers' serial numbers are an example of serialised identification.

NOTE 2 A serialized identification of measuring equipment is a quality assurance requirement.

3.43
acceptance test
⟨measuring instrument⟩ set of operations agreed upon by the measuring instrument manufacturer and the user to verify that the performance of a measuring instrument is as stated by the manufacturer

3.44
verification test
⟨measuring instrument⟩ test to verify that the performance of a measuring instrument is as stated by the user and executed according to the same procedures as those of the acceptance test

4 Abbreviations

For the purpose of this International Standard, the abbreviations of Table 1 apply.

Table 1 — Abbreviations

Abbreviation	Term	Reference
DC	Design characteristic	3.13
DR	Design requirement	3.15
MPL	Permissible limits of a metrological characteristic	3.20
LSL	Lower specification limit	ISO 14253-1:1998
ME	Measuring equipment	3.1
MC	Metrological characteristic	3.12
MR	Metrological requirement	3.14
MPE	Maximum permissible error	3.21, see also 3.19
USL	Upper specification limit	ISO 14253-1:1998

5 Design characteristics

5.1 General

5.1.1 Characteristics

Design characteristics for measuring equipment may be of interest even if they do not have a short-term influence on the measurement results (i.e. errors and uncertainty of measurement). Important design characteristics may be subject to specification by the manufacturer/supplier and/or the user/customer of the measuring equipment. The kinds of important design characteristics are dependent on the type, design and intended use of the measuring equipment.

Some design characteristics may have an influence on the equipment's long term ability to measure: for example, wear may influence some of the metrological characteristics.

5.1.2 Standards

Relevant important design characteristics are subject to standardization in the specific ISO GPS standards concerning the individual types of measuring equipment.

For the sake of interchangeability, this standardization shall be limited to the most important design characteristics, so as not to limit development of measurement technology and measuring equipment.

The specific ISO standards concerning the individual types of measuring equipment can use two levels/options for design characteristics:

— listing by the manufacturer/supplier of the design characteristics to be explicitly stated, and indicating nominal values if necessary and possible;

— listing of the design characteristics and associated values and/or tolerance limit values to be standardised.

NOTE This is the only case in future standards where values of characteristics and tolerances are standardised in ISO GPS standards for specific measuring equipment.

Those design characteristics, if any, which are of uppermost importance and therefore are to be standardised in one of the two levels/options, shall be evaluated and decided in each specific case (measuring equipment). The lists in 5.2 and 5.3 shall be used as guidance for the ISO standards on specific measuring equipment.

Generally speaking, when proving conformance or non-conformance to stated and/or chosen limit-values for design characteristics, the rules in ISO 14253-1:1998 apply.

5.1.3 Measuring equipment — Commerce

In their product documentation, data sheets, etc., intended to give customers information on the product, manufacturers and suppliers of GPS measuring equipment shall at least present the suggested design characteristics given in the relevant specific standard.

It may be in the interests of the manufacturer/supplier to supply additional relevant information about design characteristics (see Annex B).

A customer may have special requirements for additional design characteristics. This International Standard may be used as a tool to establish these specifications.

5.1.4 Measuring equipment — Internal use in a company

Design characteristics and possible requirements in MPE or MPL values shall be used in trade, but not necessarily used or verified in daily operation in a company.

Design characteristics and possible requirements standardised in an ISO standard for a specific GPS measuring equipment shall not be taken as mandatory in the daily operation of the metrology system, unless specific decisions in the organisation/company make them mandatory.

Generally speaking, an organisation or a company may establish a set of design characteristics, based on local needs and conditions, or for each group of measuring equipment. These technical decisions should also be evaluated in terms of costs and communicated on a data sheet (see Annex B).

5.2 Indicating measuring equipment

Typical design characteristics for indicating measuring equipment are related to the importance of the characteristics in the use of the equipment. The following non-exhaustive list of reasons and design characteristics shall only be considered as examples. In many cases, very specific design characteristics exist for a specific use and for specific types of measuring equipment.

— Interchangeability

EXAMPLES Overall and detail measures, measuring range, clamping and or mounting system, etc. and relevant geometry/tolerances.

— Wear resistance

EXAMPLES Material, hardness, etc. of relevant parts of the equipment.

— Environment protection

EXAMPLES Water protection, dust protection, electrical protection, corrosion protection.

— Electrical requirements

EXAMPLES Interface protocols, power supply, etc.

— Special operating features

EXAMPLES Hoisting/lifting devises, alignment devices.

— Operating limitations

EXAMPLES Maximum speed of travel, temperature range, power and air supply stability.

— Special auxiliary equipment

EXAMPLES Surface plate, v-block, clamping devices.

5.3 Material measures

Typical design characteristics for material measures are related to the importance of the characteristics in the use of the equipment. The following non-exhaustive list of reasons and design characteristics shall only be considered as examples. In many cases very specific design characteristics exist for specific types of measuring equipment.

— Interchangeability

EXAMPLES Overall and detail measures, measuring range, measuring volume, clamping and/or mounting system, etc. and relevant geometry/tolerances

— Wear resistance

EXAMPLES Material, hardness, etc. of relevant parts of the material measure.

— Environment protection

EXAMPLE Corrosion protection.

— Operating limitations

EXAMPLES Humidity, chemical environment.

— Special auxiliary equipment

EXAMPLES Surface plate, V-block, clamping devises.

6 Metrological characteristics

6.1 General

6.1.1 Characteristics

Metrological characteristics of measuring equipment are of interest for the control of errors and uncertainty contributors originating from the measuring equipment and for the evaluation of uncertainty of measurement when using the measuring equipment. The influence of the individual metrological characteristic on the uncertainty of measurement is dependant on the measurement process (verification operator). An awareness of the existence of the actual metrological characteristics and the magnitude of their values may serve as a basis for the design of the measurement process (see ISO/TS 14253-2:1999) and the choice of measuring equipment.

Repeatability of metrological characteristics is important information when assessing the measurement uncertainty.

Repeatability of a metrological characteristic (3.23) shall be expressed as the standard deviation of the variation concerned.

6.1.2 Standards for measurement equipment

Metrological characteristics relevant for common use of specific GPS measurement equipment shall be identified, designated (by name and symbol) and defined in the standards concerning the individual types of measuring equipment, with a reference to this International Standard. All MPE or MPL references for a specific metrological characteristic shall be shown with the designated symbol as a subscript. Unnecessary repetition shall thus be avoided. For the format and definition of some general metrological characteristics and their MPE or MPL values and MPE or MPL functions, see Clause 7.

The calibration of each of the chosen metrological characteristics shall be carried out with a sufficient number of different positions and nominal lengths (scale positions) and with a calibration process that has a sufficiently small measurement uncertainty. What constitutes a sufficient number of points (on the equipment and on the scale) and a sufficient measurement uncertainty shall be decided based on the actual equipment (measuring instrument and measurement standards), environmental conditions, requirements, etc.

The sufficient number of points and the choice of the position of the points on the scale shall depend on the wavelength and amplitude of the various reasons for the errors of indication. Long wavelength and small amplitudes will require fewer points than short wavelength and large amplitudes. The required number of points therefore depends on the actual design of the measuring instrument.

All metrological characteristics and their MPE or MPL are to be evaluated in accordance with ISO 1 (20 °C) unless another temperature is specified.

All metrological characteristics and their MPE or MPL values apply to the *defined operating conditions* of the specific measuring equipment, e.g. measuring forces, speed of travel, etc. Operating conditions may be given in standards for specific measuring equipment.

All metrological characteristics and their MPE or MPL values apply to all possible orientations in space, unless particular restrictions on the orientation are stated in the specific ISO standard.

The metrological characteristics mentioned in ISO standards for specific measuring equipment shall be chosen in accordance with common usage of the equipment (see 6.2). The definitions and choice of MPE or MPL (see Clause 7), and the conditions necessary to make them unambiguous, shall also conform to common usage in order to optimise the outcome and use of the specifications.

Standards for specific measuring equipment, with the exception of a few examples (i.e. ISO 1938[1] and ISO 3650[3]), shall not include any numerical values for MPEs and MPLs, but shall include empty tables for MPE or MPL values as a guidance for the user of the standard. Numeric values for MPEs (and MPLs) will normally be specified by the manufacturer, in the case of acceptance tests, and by the user, in the case of verification tests.

Generally speaking, when proving conformance or non-conformance to stated and/or chosen MPE or MPL values, the rules in ISO 14253-1:1998 apply.

6.1.3 Measuring equipment — Commerce

For acceptance tests, MPE or MPL values or functions for metrological characteristics shall be supplied by the manufacturer/supplier.

The manufacturer may add additional information about metrological characteristics and their MPE or MPL values. The manufacturer may set up restrictions and operating conditions not stated in this standard or in the standard for the specific measuring equipment.

This information about MPE or MPL values, additions, conditions and restrictions shall be indicated by the supplier in data sheets or other documents. The user notes down these requirements on a data sheet (see Annex B).

6.1.4 Measuring equipment — Internal use in a company

The customer shall identify and understand the major metrological characteristics by means of uncertainty budgeting (see examples in ISO/TS 14253-2:1999). Expert judgement and previous knowledge can be used in the uncertainty estimation procedure. Calibration procedures can also be decided on the basis of uncertainty budgeting using expert judgement and previous knowledge.

Calibration of metrological characteristics shall take into account the repeatability of the metrological characteristics, whether by investigation or by previous knowledge. For economic reasons, this should be the initial activity in the calibration procedure.

For internal calibrations and for verification tests, MPE or MPL values or functions for metrological characteristics shall be supplied by the user.

6.2 Identification, definition and choice of metrological characteristics

Metrological characteristics of measuring equipment may be chosen and defined in several ways. As far as possible, metrological characteristics and the definition of the requirements (MPE or MPL definitions) for these characteristics, including the necessary conditions, shall be chosen and defined with respect to:

— the common intended use of the equipment (i.e. usual GPS operations and operators) — common uncertainty budgets may be used for guidance;

— the independence of other metrological characteristics;

- the uncertainty in measurement of the equipment in the measuring process;
- the relevance of the physical principles inherent in the measuring equipment;
- the use in maintenance activities and error identification;
- the relation to specific parts and/or functions in the measuring equipment;
- the measuring principle or method;
- the relevance of magnitude compared to the other metrological characteristics.

In special cases, it may be beneficial for a user of measurement equipment to define metrological characteristics other than those given in the standards, in order to better fit the needs and intended use of the measurement equipment.

6.3 Indicating measuring equipment — Identification of general metrological characteristics

6.3.1 General

In many cases, the following metrological characteristics will be relevant for indicating measuring equipment. The definitions of the type of specification, MPE or MPL type, are described in Clause 7.

6.3.2 Scale interval — Resolution of reading

6.3.2.1 General

In analogue measuring equipment, the scale interval or the resolution of reading, or both the scale interval and the resolution, are relevant metrological characteristics and shall be stated in ISO standards for specific measuring equipment. The smaller of the scale intervals, or the resolution of an analog and digital step for digital read outs, sets a lower limit for the uncertainty contributions from the equipment.

6.3.2.2 Scale interval

A "**scale interval**" (3.28.2) and a "vernier scale interval" are to be understood in a similar way, but the vernier difference is the (main) scale interval divided by the number of vernier intervals (sub-divisions), usually 10. A reading on a vernier scale takes place when a main scale line is in nearest coincidence with a vernier scale line.

6.3.2.3 Resolution of reading

The **resolution** (3.26) can be smaller than the scale interval, but this is dependant on the design of the scale and the quality of the scale marks and pointer.

6.3.3 Digital step

Digital step (3.27) is the resolution of a digital readout, and is therefore mandatory information.

6.3.4 Error of indication

Error of indication (3.16) shall be defined and stated as an MPE function, with reference to one of the possibilities given in Clause 7. It is of uppermost importance to state the conditions, e.g.:

- fixed or floating zero;
- direction of travel or both directions of travel included (hysteresis included);

— other conditions, e.g. orientation in space, maximum speed of travel, etc.

In ISO standards for specific measuring equipment, the MPE function may be given as an equation between the parameter symbols (no values) of points on the MPE function and/or a table giving the symbols and having empty cells for the values of the parameters. The mandatory measuring points given in Clause 7 shall be respected.

6.3.5 Error-of-indication span, h

The error-of-indication span, h (see Figure 5 and 7.5.2), is a simplified method to specify the constant MPE function for floating zero error of indication in a specified range, often the measuring range.

NOTE The error-of-indication span can be misleading, because it can only be made visible on a fixed zero error curve, but in itself, it is a parameter of the equipment when the measuring equipment is used in floating zero mode.

6.3.6 Hysteresis

Hysteresis (3.24) of indication shall be understood as the mean difference in a specified range between values of indication taken at the same true value with two different orientations of travel. When the range is not stated, it is the measuring range. The standard deviation of the variation, or the maximum value of the individual values of hysteresis, is also important.

Hysteresis may, for simplification, be included in the error-of-indication MPE function, which covers both directions of travel. Hysteresis may be of interest in connection with other metrological characteristics.

6.3.7 Temperature-related characteristics

Temperature expansion properties shall be given as an “effective temperature expansion coefficient” relevant to the effect of temperature on the measurand and/or the zero point. The uncertainty on the stated value shall be given if relevant.

For some measuring equipment, the time constant, T_C, for the temperature change of measuring equipment is important information and may be given as additional information. The time constant shall be defined as the time needed to reduce by 50 % the temperature difference between the equipment and the ambient air, etc., under stable temperature conditions and in normal operation.

6.3.8 Characteristics related to measuring force

MPL values or functions for measuring forces shall be a metrological requirement, if relevant. For reasons of interchangeability, values for specific measuring equipment may also be given in the ISO standards as design requirements.

The repeatability of measuring force is an important characteristic in many cases, but the effect may be included in the repeatability of indication. Only in special cases is the repeatability of measuring force(s) of specific interest.

The influence of gravity forces, i.e. the orientation in space, is an important characteristic and shall be stated if necessary. Orientation and gravity forces may influence the zero error and the shape of the error-of-indication curve. The general requirement in ISO GPS standards is that the metrological characteristics and MPLs given shall apply for any orientation in space of the measuring equipment.

The effect of side forces on the active part of the contact geometry may be an issue, and shall be stated and specified if necessary.

6.3.9 Contact geometry

Contact geometry, i.e. rounding, truncation, surface texture, etc. may influence the measurement result and shall be stated as requirements, if necessary.

6.3.10 Other possible metrological characteristics

A number of additional metrological characteristics exist. Examples are:

- parallax — index/scale marks;
- threshold — stick slip;
- time stability [e.g., CMM (form, etc.), laser diodes];
- response characteristic — speed/time;
- locking mechanisms.

6.3.11 Auxiliary equipment

When measuring equipment is mounted in auxiliary equipment during operation, the auxiliary equipment may also add uncertainty contributions. Therefore, auxiliary equipment may also be subject to metrological characteristic requirements.

A common example where the characteristic of a piece of auxiliary equipment influences the measurements is shown on Figure 4. The measuring stand is an important part of the measuring loop. The measurements are influenced by the stiffness of the stand, the temperature and the temperature gradients of the measuring stand.

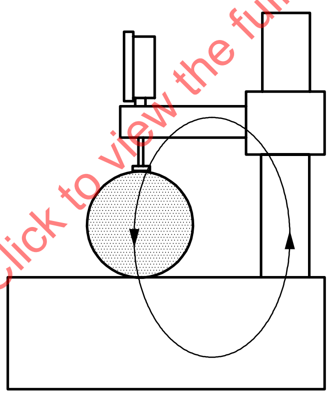


Figure 4 — Measuring loop in auxiliary equipment

6.4 Material measures — Identification of general metrological characteristics

6.4.1 General

In many cases, the following metrological characteristics will be relevant for a material measure. The definitions of the types of specification, MPE or MPL type, are described in Clause 7.

6.4.2 Scale interval — Resolution of reading

6.4.2.1 General

In the case of a graduated material measure, the scale interval or the resolution of reading, or both the scale interval and the resolution, shall be given in the specifications (see 6.3.2).

6.4.2.2 Scale interval

See 6.3.2.2

6.4.2.3 Resolution of reading

See 6.3.2.3

6.4.3 Form of feature characteristics

Form specifications for geometrical features of a material measure shall be given with reference to ISO 1101 and other ISO standards. As far as possible, the characteristics and error of the form of the relevant measurand inherent in the material measure shall be defined independently of each other.

Cases exist where it is necessary to combine dimensional and geometrical specifications through the use of the maximum material requirement (see ISO 2692).

6.4.4 Relative orientation of feature characteristics

Angular specifications (relative orientation between features in a material measure) shall be given with reference to ISO 1101, ISO 5459 and other ISO standards. As far as possible, angular characteristics and error of the relevant measurand inherent in the material measure shall be defined independently of each other.

Cases exist where it is necessary to combine dimensional and geometrical specifications through the use of the maximum material requirement (see ISO 2692).

6.4.5 Effective temperature expansion coefficient

Temperature expansion shall be given as an “effective temperature expansion coefficient” relevant to the effect of temperature on the geometrical characteristic represented by the material measure. The uncertainty of the stated value shall be given if relevant.

For some material measures, the time constant, T_C, for the temperature change of a material measure is important information and may be given as additional information. The time constant shall be defined as the time needed to reduce by 50 % the temperature difference between the material measure and the ambient air, etc. under stable temperature conditions and in normal operation.

6.4.6 Long term stability

For special material measures, the stability of the equipment in time is a relevant and important metrological characteristic. In these cases, this characteristic shall be included in the ISO standard for the specific material measure.

EXAMPLES Gauge blocks, step gauges and high precision line scales.

6.4.7 Other possible metrological characteristics

A number of additional metrological characteristics may exist. Examples are:

— effective Young’s modulus;

— orientation and support sensitivity;

— measuring force and gravity force sensitivity;

— effect of contact geometry.

7 Types of presentation and types of specifications for characteristics

7.1 General

Metrological characteristics of measuring equipment can be characterised by:

- a single characteristic value or error;
- a series of characteristic values or errors, or functions of values or errors.

Single characteristic values may be based on a reference point or may be unrelated depending on the nature of the characteristic. A series of characteristic values always has corresponding values of, for example, a nominal or true value of another parameter (e.g. the nominal value), forming coordinate-pairs (points), e.g. in a diagram. The lines connecting the points in the diagram form a characteristic curve or an error curve representing the characteristic in a range (see Figure 5). The values in the characteristic curve or the error curve may be different, depending on which point in the range is chosen as the reference point.

Operating conditions shall be described/defined in connection with specifications/requirements for characteristics.

7.2 Presentation of characteristic curves — Fixed and floating zero

7.2.1 General

The most frequent use of characteristic curves is as different kinds of error-of-indication curves for indicating measuring equipment. More rarely, curves are used for other characteristics. The measuring force for dial gauges is one example. The choice between using the fixed or the floating zero curve is dependent on the nature of the characteristic and/or calibration method. It is possible to derive the floating zero curve from the fixed zero curve.

7.2.2 Fixed zero or fixed reference point

Characteristic curves are most often drawn with the zero-point of indication as the fixed zero (see Table 2 and Figure 5 as an example of fixed zero). Figure 7 is an example of a transformation of the data shown in Figure 5 to a floating zero representation.

When the fixed zero is moved from the zero indication point to other measuring points in the actual range of the measuring equipment, the error curve moves vertically in the diagram, and there are changes in the largest (possible) negative and positive errors of indication, h_n and h_p respectively (see Figure 6).

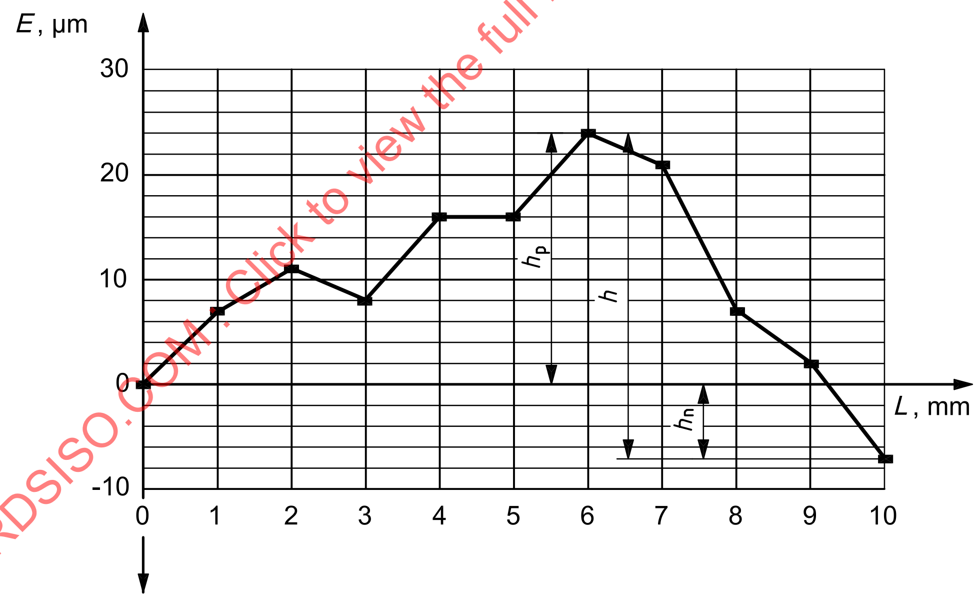
The error-of-indication span, h, and the shape of the error curve do not change.

The movement of a fixed zero is equivalent to adjustment to the zero error of indication in different measuring points in the range.

To avoid ambiguity, the fixed zero shall be defined and reported when an error of indication is reported for measuring equipment.

Table 2 — Example of errors of indication for the same measuring equipment with different reference points

Reference point mm	Length indication mm										
	0	1	2	3	4	5	6	7	8	9	10
	Error µm										
0	0	7	11	8	16	16	24	21	7	2	–7
6	–24	–17	–13	–16	–8	–8	0	–3	–17	–22	–31
10	7	14	18	15	23	23	31	28	14	9	0



Key

h error-of-indication span

h_p largest positive error (fixed zero = 0)

h_n largest negative error (fixed zero = 0)

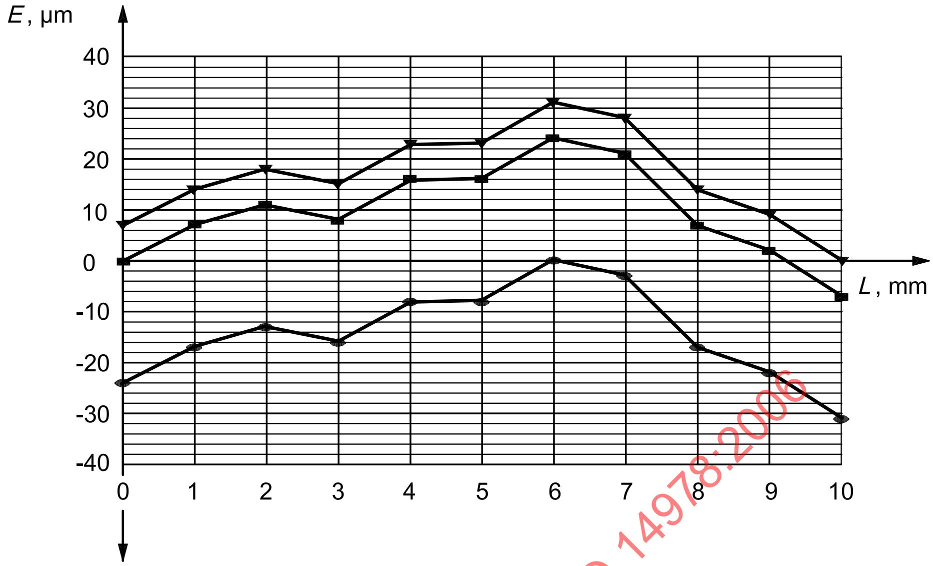
L length indication

E error

NOTE 1 Fixed zero at zero indication point (data from Table 2).

NOTE 2 See also 7.5.2 for the meaning of h.

Figure 5 — Example of an error-of-indication curve



Key

L length indication

E error

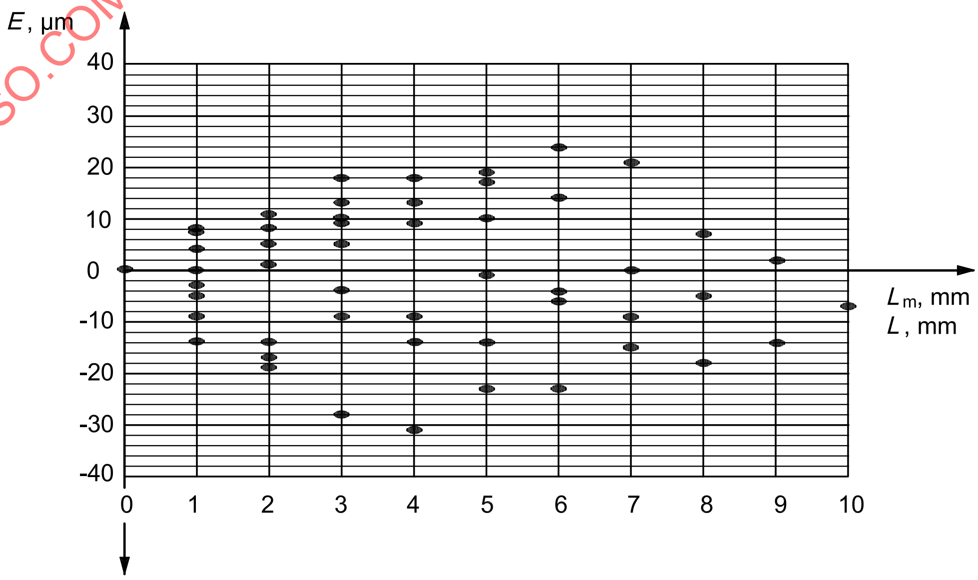
NOTE 1 Fixed zero at indication points 0, 6 and 10 mm (data from Table 2).

NOTE 2 The error-of-indication curve may also be given as a polar plot or with logarithmic scale(s) if applicable .

Figure 6 — Example of error-of-indication curves

7.2.3 Floating zero or reference point

The information immediately intelligible from an error curve, e.g. that shown in Figure 5, is not suitable for the actual measuring process, when the zero is floating. A floating zero is often part of the procedure when digital indicating measuring equipment is used, but analog equipment, such as line scales and mechanical dial indicators, is also often used with floating zero.



Key

L_m measured length

L length indication

E error

NOTE The same data and measuring equipment have been used as in Table 2, Figures 5 and 6.

Figure 7 — Example of errors of indication with floating zero

Figure 7 presents errors of indication with a floating zero. The floating zero error is based on any measured length of a certain magnitude, not only on the length from the reference point. The floating zero errors can be derived from the fixed zero error curve.

Taking the fixed error curve of Table 2 and Figure 5 as an example:

— errors in measurement over 1 mm measurements can be derived 10 times as the differences in error over 10 mm measuring lengths;

— errors over 2 mm can be derived 9 times;

— etc.;

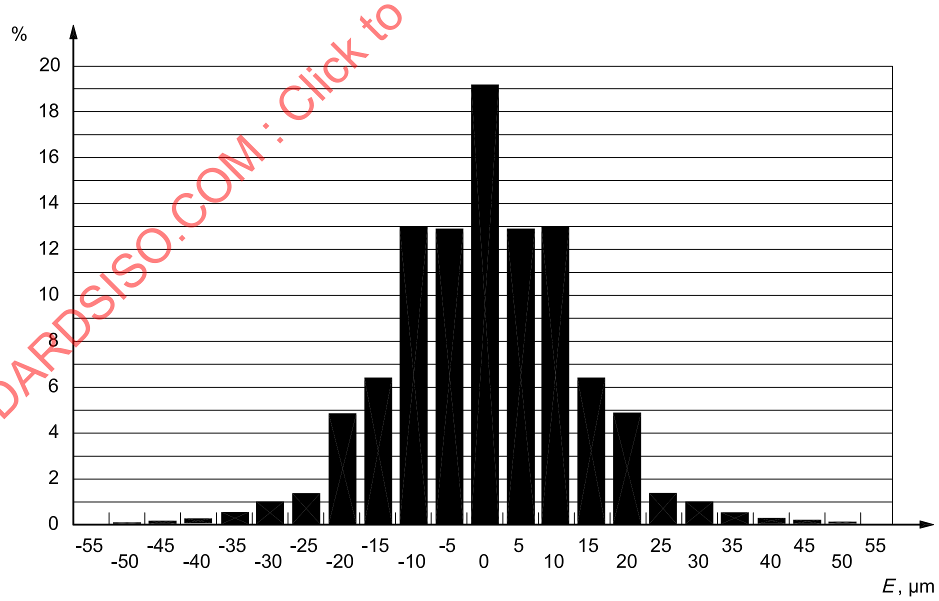
— an error in measurement over 10 mm can only be found once.

The largest floating zero error will always be the full error range in the fixed zero error curve, h (see Figure 5). The distribution of error values on the different measured lengths depends on the shape and details of the fixed zero error curve. Figure 7 is given only as an example.

7.3 Presentation of a characteristic — Statistical

When the amount of data in a floating zero presentation is large, the error-of-indication can also be presented as a frequency distribution (see Figure 8). A frequency distribution diagram represents only one measured length. This method of presentation often applies for a group of identical measurement equipment and/or for small measured lengths.

It is obvious that the frequency distribution also can be represented by its standard deviation. In the example of Figure 8, the standard deviation is approximately 13,0 µm. The standard deviation adjusts directly, like the uncertainty contributor in the uncertainty budget in GUM or ISO/TS 14253-2:1999.



Key

E error

NOTE Floating zero, measured length 1 mm.

Figure 8 — Example of error-of-indication frequency distribution

For larger measured lengths in relation to the measuring range of the measuring equipment, the frequency distribution may degenerate into distribution types more difficult to evaluate.

7.4 Specifications for single-value metrological characteristics

Specifications for single-value characteristics of measuring equipment, in the field of GPS, shall be defined and given as MPE or MPL values.

NOTE In some cases design characteristics are specified only by a nominal value.

MPE or MPL values may be given as a one-sided specification, with USL or LSL for a characteristic. MPE or MPL may also be given as a two-sided specification, USL and LSL.

In cases where specifications for single-value characteristics are given as MPE or MPL values, ISO 14253-1:1998 applies.

7.5 Specification for metrological characteristics defined in a range

7.5.1 General

Specifications for characteristics of measuring equipment in the field of GPS, defined in a range, shall be defined and given as a continuous MPE or MPL function:

MPE = f(relevant parameter)

When indicating MPE or MPL values, the +/– symbol shall be used for symmetrical situations; for single sided situations the + or – symbol shall be used. For asymmetrical situations the + and – symbols shall be used.

The relevant parameter is most often the true value of indication of the measuring equipment. The continuous MPE or MPL functions shall preferably be straight lines. MPE or MPL functions are limiting functions for a characteristic of the measuring equipment in a specified range within the measuring range. MPE or MPL functions may be given as a one-sided specification, USL or LSL. MPE or MPL functions are most frequently given as two-sided specifications, USL and LSL.

Error-of-indication and related characteristics, and MPE or MPL functions, are usually given as symmetrical specifications, limiting the absolute value of the error (see Figures 9, 10 and 11). Other characteristics may be limited by two-sided MPL specifications in a more usual way, see Figure 12 as an example.

MPE or MPL functions may be used for the specification of measuring equipment characteristics for fixed zero errors and floating zero errors.

NOTE It is important to realise that the fixed zero and the floating zero result in two different MPE or MPL functions for the same measuring equipment.

A set of MPE standard deviations, in accordance with 7.3, may be used as a special way to set up a specification.

Generally speaking, ISO 14253-1 applies.

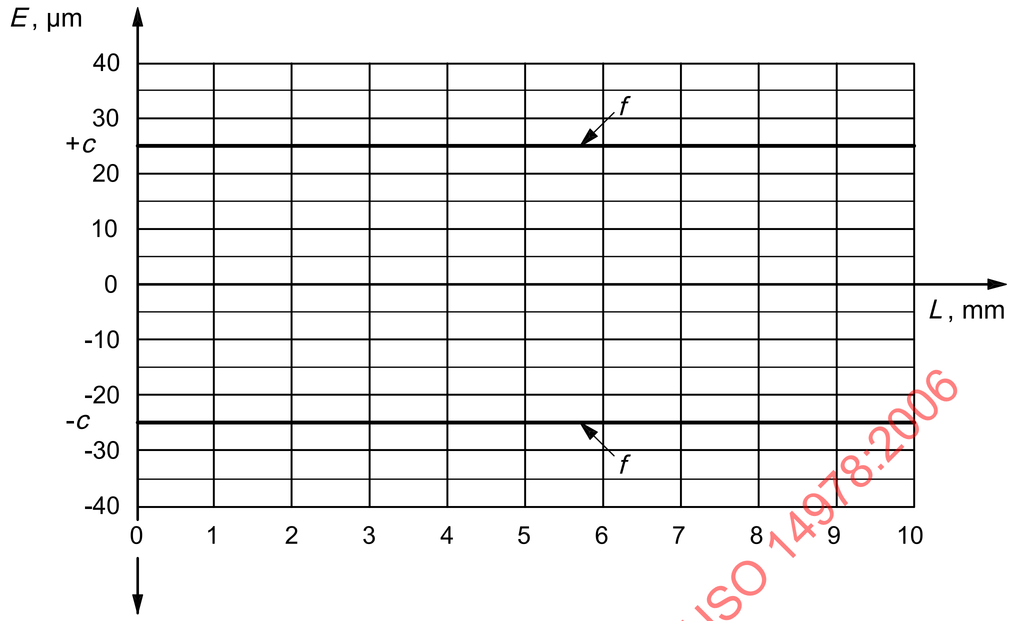
7.5.2 The MPE function is a constant value or values

MPE functions with a constant value may be specified in two ways. The most simple MPE function is a constant c ($c > 0$).

Upper limit MPE = c

Lower limit MPE = $-c$

in the measuring range (see Figure 9).



Key

L length indication

E error

f MPE function

Figure 9 — Example of MPE function with a constant value, c, limiting the absolute value of the error

In connection with this requirement, it shall be stated clearly whether it applies to a fixed or a floating zero, and whether it is a one-sided (USL or LSL) or symmetrical (USL and LSL) specification, limiting the absolute value of the error.

A second way to define a constant MPE function applies to the range of errors-of-indication of an instrument. In this case the function is

Range MPE = c

NOTE 1 This MPE applies to the full range of fixed zero errors.

With reference to Figure 5, the value h could be compared to c for evaluation purposes.

In the case of floating zero specifications, this method does not apply, because the evaluation of floating zero errors (as shown in Figure 7) already includes an evaluation of the full range error as one of the possible floating zero errors. For floating zero errors, only the MPE function defined above should be used, because the zero point could be set to either the location of the most positive error or the location of the most negative error.

NOTE 2 This method, used alone, is often an uneconomical way to specify the errors of a metrological characteristic of measuring equipment.

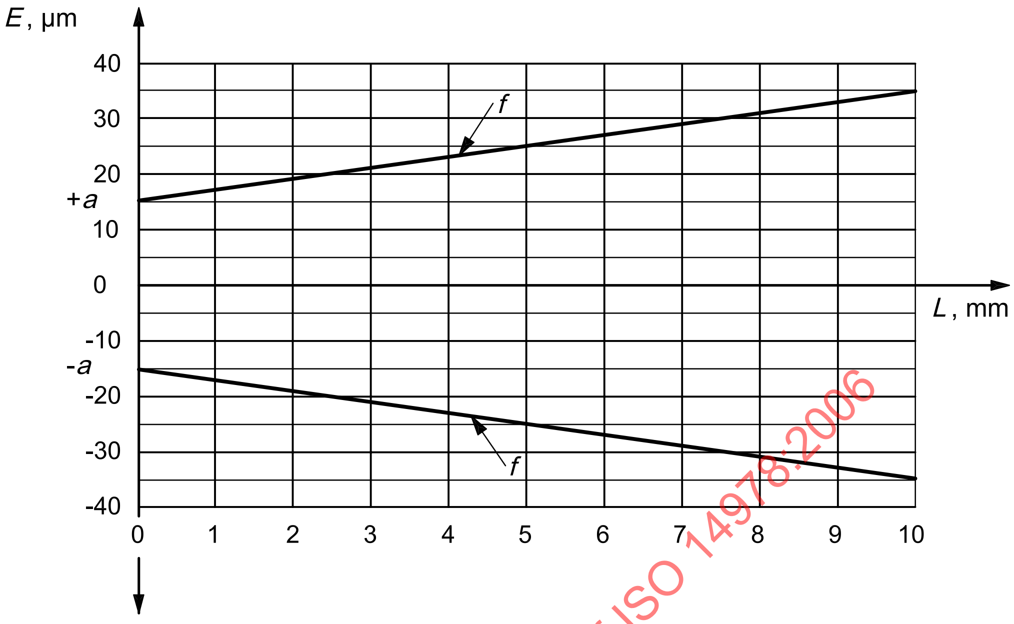
7.5.3 The MPE function is a proportional value

Upper limit MPE = + $(a + L \times b)$;

Lower limit MPE = – $(a + L \times b)$

where L is the distance from the reference point in the case of a fixed zero and L is the measured length in the case of a floating zero, and $a > 0$ and $b > 0$.

The MPE function may be given as a table. The values in the table shall be chosen as coordinates (pairs of values) on the limiting lines. The values at the ends of the measuring range are mandatory in the table.



Key

L length indication

E error

f MPE function

Figure 10 — Example of MPE function with a proportional value limiting the absolute value of the error

In connection with this requirement, it shall be stated clearly whether it applies to a fixed or a floating zero, and whether it is a one-sided (USL or LSL) or symmetrical (USL and LSL) specification, limiting the absolute value of the error.

7.5.4 The MPE function is a proportional value and a maximum value

Upper limit MPE $= (a + L \times b)$ for $0 < L \leqslant L_1$

Lower limit MPE $= -(a + L \times b)$ for $0 < L \leqslant L_1$

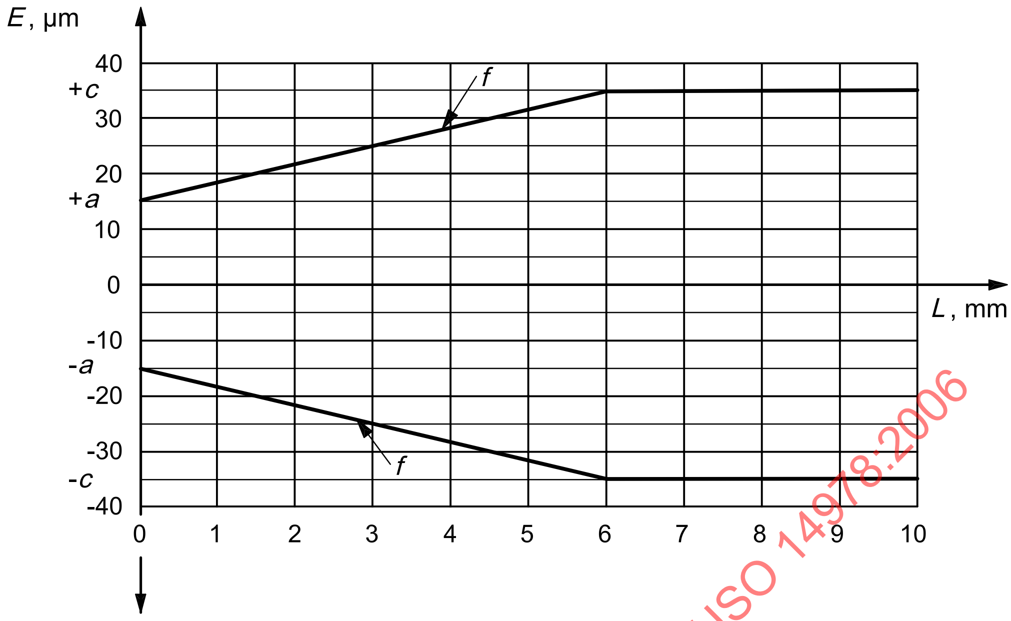
Upper limit MPE $= c$ for $L \geqslant L_1$

Lower limit MPE $= -c$ for $L \geqslant L_1$

where L is the distance from the reference point in the case of a fixed zero and L is the measured length in the case of a floating zero, and $a > 0$ and $b > 0$.

The MPE function may be given as a table. The values in the table shall be chosen as coordinates (pairs of values) on the limiting lines. The values at the ends of the measuring range and the transition point are mandatory in the table.

In connection with this requirement, it shall be stated clearly whether it applies to a fixed or a floating zero, and whether it is a one-sided (USL or LSL) or symmetrical (USL and LSL) specification, limiting the absolute value of the error.



Key

L length indication

E error

f MPE function

Figure 11 — Example of MPE function with a proportional value and a maximum value, *c*, limiting the absolute value of the error

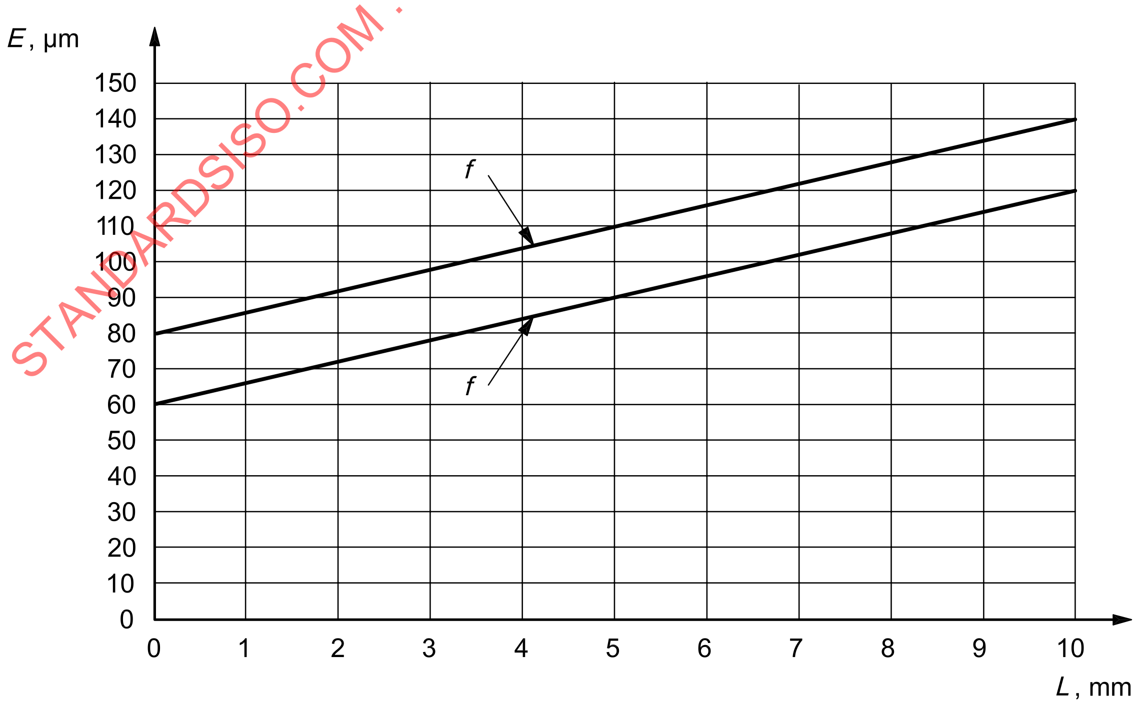
7.5.5 Two sided MPL function for a metrological characteristic

$$\text{MPL(USL)} = a_1 + L \times b$$

$$\text{MPL(LSL)} = a_2 + L \times b$$

Figure 12 illustrates a common method to define and provide two-sided specifications (MPL functions) in a range for characteristics other than metrological characteristics. It is always used with the fixed zero and the zero point as the reference point.

NOTE An example is the measuring force for mechanical dial gauges.



Key

L length indication

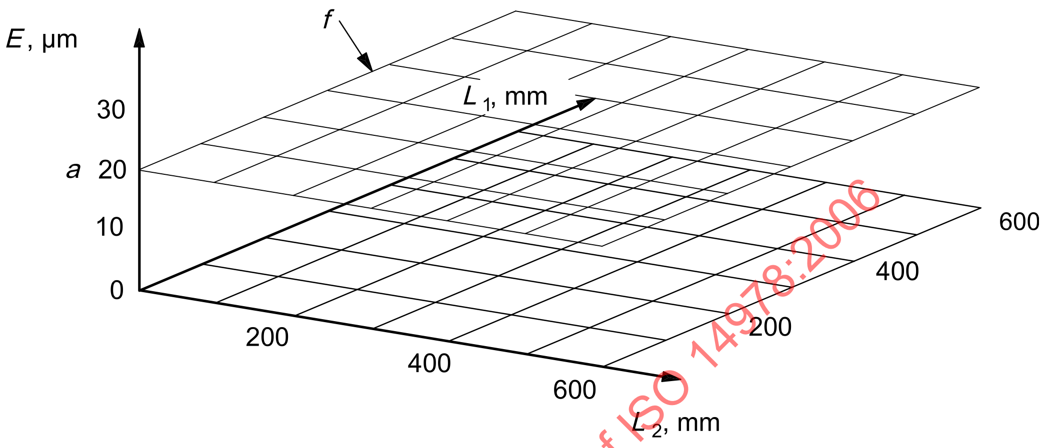
E error

f MPL function

Figure 12 — Example of a two-sided MPL specification limiting the values of the characteristic in the measuring range with two MPL functions

7.6 Specification for metrological characteristics defined in a two- or three-dimensional range

The MPE or MPL functions given in 7.5 may also be used in two- and three-dimensional ranges (area and volume), see Figure 13. For two- and three-dimensional instruments, only the floating zero applies.



Key

L_1 length indication 1

L_2 length indication 2

E error

f MPE function

Figure 13 — Example of a two-dimensional MPE requirement with a constant MPE = a over the whole area

8 Calibration of metrological characteristics

8.1 Manufacturer and supplier of measuring instruments

The manufacturer and/or the supplier shall calibrate the suggested metrological characteristics and document the conformance with the stated MPE values.

8.2 User of measuring instruments

The metrological characteristics necessary for the intended use of the instrument shall be chosen and shall be verified by calibration (or verification tests.) The calibrated value(s) of the metrological characteristic(s) shall be stated with the related measurement uncertainty/uncertainties, and/or the calibrated values of the metrological characteristic shall be proven to be in conformance with the actual MPE value(s).

NOTE In normal use of measuring instruments it is often possible and appropriate to limit the number of requirements (different MPEs) and the extent of resources used to prove that the measuring instrument functions in accordance with the set-up requirements (MPLs and MPEs).

8.3 Measurement uncertainty

The acceptability of the amount of measurement uncertainty influences the number of points required to prove that a measuring instrument has a particular metrological characteristic function, and/or that this metrological characteristic is in conformance with a particular MPE value or function. A large number of points reduces the measurement uncertainty. A small number of points increases the measurement uncertainty. The required number of points therefore depends on the acceptability of the measurement uncertainty.