TECHNICAL SPECIFICATION

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Geometrical product specifications (GPS) — General concepts —

Part 2: Basic tenets, specifications, operators and uncertainties

Spécification géométrique des produits (GPS) — Concepts généraux —

Partie 2: Principes de base, spécifications, opérateurs et incertitudes

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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 3.

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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years with a view to deciding whether it should be confirmed for a further three years, revised to become an International Standard, or withdrawn. In the case of a confirmed ISO/PAS or ISO/TS, it is reviewed again after six years at which time it has to be either transposed into an International Standard or withdrawn.

Attention is drawn to the possibility that some of the elements of this part of ISO/TS 17450 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 17450-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO/TS 17450 consists of the following parts, under the general title *Geometrical product specifications (GPS) — General concepts*:

— *Part 1: Model for geometric specification and verification*

— *Part 2: Basic tenets, specifications, operators and uncertainties*

Annexes A, B and C of this part of ISO/TS 17450 are for information only.

Introduction

This part of ISO/TS 17450 is a geometrical product specification (GPS) document and is to be regarded as a global GPS document (see ISO/TR 14638). It influences all chain links of the chains of standards.

For more detailed information on the relationship of this part of ISO/TS 17450 to other standards and to the GPS matrix model, see annex C.

This part of ISO/TS 17450 covers several fundamental issues common to all the GPS standards developed by ISO/TC 213 and, by presenting GPS's basic tenets and specification and verification processes, explains some of the underlying ideas and indicates the starting point for the standards developed by this technical committee.

It must be pointed out that these ideas — and, for that matter, all the other ideas and concepts applied by ISO/TC 213 — are subject to development and refinement, as the TC's recognition and understanding of them further evolves during its ongoing standards work.

Geometrical product specifications (GPS) — General concepts —

Part 2:
Basic tenets, specifications, operators and uncertainties

1 Scope

This part of ISO/TS 17450 defines terms related to specifications, operators (and operations) and uncertainties used in geometrical product specifications (GPS) standards, presents the basic tenets of the GPS philosophy while discussing the impact of uncertainty on those tenets, and examines the processes of specification and verification as they apply to GPS.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO/TS 17450. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO/TS 17450 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 in product verification*

ISO 14660-1:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

ISO 14978:—[1], *Geometrical Product Specifications (GPS) — General concepts and requirements for GPS measurement equipment*

ISO/TS 17450-1:2001, *Geometrical product specifications (GPS) — General concepts — Part 2: Model for geometric specification and verification*

Guide to the Expression of Uncertainty in Measurement (GUM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1st edition, 1993, corrected and reprinted, 1995

International Vocabulary of Basic and General Terms in Metrology (VIM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 2nd edition, 1993

1) To be published.

3 Terms and definitions

For the purposes of this part of ISO/TS 17450, the terms and definitions given in ISO/TS 14253-2, ISO 14660-1, ISO 14978, ISO/TS 17450-1, GUM, VIM and the following apply. See annex A, Figure A.1, for a concept diagram giving an overview of the relationships between these terms, which it is recommended be read first.

3.1 Generic term

3.1.1
metrological characteristic deviation
deviation from a ideal metrological characteristic value

See ISO/TS 17450-1.

NOTE The metrological characteristic deviation of measuring equipment includes those originating from scales, guideways, software, magnification, non-stiffness of the equipment, etc.

3.2 Terms related to operations

3.2.1
specification operation
operation formulated using only mathematical or geometrical expressions or algorithms, or all these

NOTE 1 Specification operations are used in the geometrical field of mechanical engineering to specify a requirement to a product as part of a **specification operator** (3.3.3).

NOTE 2 Specification operation is a theoretical concept.

EXAMPLE 1 The association of a minimum circumscribed cylinder in the specification of the diameter of a shaft.

EXAMPLE 2 The filtration by a Gaussian filter in the specification of surface texture.

3.2.2
default specification operation
specification operation (3.2.1) required by standards, regulations etc. when the ISO **basic GPS specification** (3.5.4) is used without modifiers in the **actual GPS specification** (3.5.6)

NOTE 1 The default specification operation may be a global default (ISO default), company default or drawing default specification operation.

EXAMPLE 1 The evaluation of a two-point diameter in the specification of the diameter of a shaft using the default indication ∅ 30 ± 0,1.

EXAMPLE 2 The filtration by a Gaussian filter (default filter) with the default cut-off length given by the default rules in ISO 4288 in the specification of Ra for a surface.

3.2.3
special specification operation
specification operation (3.2.1) specifically required when the ISO **basic GPS specification** (3.5.4) is used with modifiers, thus overriding a **default specification operation** (3.2.2)

NOTE A special specification is a non-default specification.

EXAMPLE 1 The association of a minimum circumscribed cylinder in the specification of the diameter of a shaft, when the modifier symbol, Ⓔ , for envelope, is used (see ISO 14405).

EXAMPLE 2 The filtration by a Gaussian filter (default filter) with a special cut-off length of 2,5 mm in the specification of Ra for a surface, when the appropriate indication is used to override the default rules in ISO 4288.

3.2.4
actual specification operation
specification operation (3.2.1) indicated implicitly or explicitly in the technical product documentation at hand

NOTE An actual specification operation can be

— indicated implicitly by an ISO **basic GPS specification** (3.5.5),

— indicated explicitly by a **GPS specification element** (3.5.1),

— missing.

EXAMPLE 1 The evaluation of a two-point default diameter in an actual specification operation, such as when the specification ∅ 30 ± 0,1 is used (see ISO 14405).

EXAMPLE 2 The filtration by a Gaussian filter (default filter) with a special cut-off length of 2,5 mm and the calculation by the *Ra* algorithm are two actual specification operations, when the specification indicates *Ra* 1,5 using a 2,5 mm filter.

3.2.5
verification operation
operation implemented in a measurement or measurement apparatus, or both, of the corresponding **actual specification operation** (3.2.4)

NOTE Verification operations are used in the geometrical field of mechanical engineering to verify a product to the corresponding **specification operation** (3.2.1).

EXAMPLE 1 The evaluation of a two-point diameter when verifying the diameter of a shaft — using a micrometer, for instance.

EXAMPLE 2 The extraction of data points from a surface for surface finish verification using a nominal stylus tip radius of 2 µm and a sample spacing of 0,5 µm.

3.2.6
perfect verification operation
verification operation (3.2.5) with no intentional deviations from the corresponding **actual specification operation** (3.2.4)

NOTE 1 The only measurement uncertainty contributions from a perfect verification operation are from **metrological characteristic deviation**(s) (3.1.1) in the implementation of the operation.

NOTE 2 The purpose of calibration is generally to evaluate the magnitude of these measurement uncertainty contributors originating from the measuring equipment.

EXAMPLE The extraction of data points from a surface using a nominal stylus tip radius of 2 µm and a sample spacing of 0,5 µm during the verification of the surface finish, when this is the extraction operation indicated in the specification.

3.2.7
simplified verification operation
verification operation (3.2.5) with intentional deviations from the corresponding actual **specification operation** (3.2.4)

NOTE These intentional deviations cause measurement uncertainty contributions in addition to the measurement uncertainty contributions from the **metrological characteristic deviation(s)** (3.1.1) in the implementation of the operation.

EXAMPLE The association of a two-point diameter in the verification of the size of a shaft — using a micrometer, for instance — when the specification indicates that the minimum circumscribed cylinder association is to be used.

3.2.8
actual verification operation
verification operation (3.2.5) used in the actual measurement process

3.3 Terms related to operators

3.3.1
operator
ordered set of operations

See ISO/TS 17450-1.

3.3.2
functional operator
operator (3.3.1) with perfect correlation to the intended function of the workpiece/feature

NOTE 1 While a functional operator in most cases cannot formally be expressed as an ordered set of well-defined operations, it can conceptually be thought of as a set of **specification operation(s)** (3.2.1) or **verification operation(s)** (3.2.5) that would exactly describe the functional requirements of the workpiece.

NOTE 2 The functional operator is an idealized concept used, for comparison purposes only, to evaluate how well a **specification operator** (3.3.3) or **verification operator** (3.3.9) expresses the functional requirements.

EXAMPLE The ability of a shaft to run in a hole with a seal for 2 000 h without leaking.

3.3.3
specification operator
ordered set of **specification operation(s)** (3.2.1)

NOTE 1 The specification operator is the result of the full interpretation of the combination of the **GPS specification**(s) (3.5.3) indicated in the technical product documentation according to ISO GPS standards.

NOTE 2 A specification operator can be incomplete and could, in such case, introduce **specification uncertainty** (3.4.3).

NOTE 3 A specification operator is intended to define, for example, a specific possible “diameter” in a cylinder (two-point diameter, minimum circumscribed circle diameter, maximum inscribed circle diameter, least squares circle diameter, etc.), and not the generic concept “diameter”.

NOTE 4 The difference between the specification operator and the **functional operator** (3.3.2) causes **correlation uncertainty** (3.4.4).

EXAMPLE If the specification for a shaft were ∅ 30 h7 (see ISO 286-1 and ISO 14405), then the specification operators for the upper and lower limits would be

— partition from the skin model of the non-ideal cylindrical surface,
— association of an ideal feature of type cylinder with the least squares criteria of association,
— construction of straight lines perpendicular to and penetrating the axis of the associated cylinder,
— extraction of two points for each straight line, and
— evaluation of the distance between each set of two points, the largest distance being compared to the upper limit and the smallest distance to the lower limit.

3.3.4
complete specification operator
specification operator (3.3.3) based on an ordered and full set of completely defined **specification operation(s)** (3.2.1)

NOTE A complete specification operator is unambiguous and therefore has no **specification uncertainty** (3.4.3).

EXAMPLE 1 The specification of local diameter, defining which two points are to be extracted and how the association is to be done (distance between the two points).

EXAMPLE 2 See the example for 3.3.3.

3.3.5
incomplete specification operator
specification operator (3.3.3) with one or more **specification operation(s)** (3.2.1) either missing, incompletely defined or unordered, or all three

NOTE 1 An incomplete specification operator is ambiguous and therefore introduces **specification uncertainty** (3.4.3).

NOTE 2 In order to establish the corresponding **perfect verification operator** (3.3.10), when an incomplete specification operator is given, it is necessary to choose a **complete specification operator** (3.3.4) by adding operations or parts of operations missing in the incomplete specification operator. See also **method uncertainty** (3.4.5).

EXAMPLE The specification of the step dimension 30 ± 0,1, which does not specify the association to be used.

3.3.6
default specification operator
ordered set of **default specification operation(s)** (3.2.2) only, in the default order

NOTE 1 The default specification operator can be

— an ISO default specification operator specified by ISO standards, or

— a national default specification operator specified by national standards, or

— a company default specification operator specified by company standards/documents, or

— a drawing default specification operator indicated on the drawing according to one of the above (see annex B).

NOTE 2 A default specification operator can be either a **complete specification operator** (3.3.4) or an **incomplete specification operator** (3.3.5).

EXAMPLE In accordance with ISO standards, the specification of *Ra* 1,5 indicates

— partition from the skin model of a non-ideal surface,

— partition of non-ideal lines from this non-ideal surface in multiples places,

— extraction using the evaluation length given in ISO 4288,

— filtration using a Gaussian filter with a cut-off wavelength determined by the rules in ISO 4288 and that the corresponding stylus tip radius and sample spacing are to be used, and

— evaluation of *Ra* value as defined in ISO 4287 and ISO 4288 (16 % rule).

Since each of these operations is a default specification operation and they are to be used in the default order, the **specification operator** (3.3.3) is a default specification operator.

3.3.7
special specification operator
specification operator (3.3.3) including one or more **special specification operation(s)** (3.2.3)

NOTE 1 The special specification operator is defined by a **GPS specification** (3.5.3).

NOTE 2 A special specification operator may be a **complete specification operator** (3.3.4) or an **incomplete specification operator** (3.3.5).

EXAMPLE 1 The specification for a shaft of ∅ 30 ± 0,1 Ⓔ is a special specification operator, because one of the **specification operation(s)** (3.2.1), the association of the minimum circumscribed cylinder, is not a **default specification operation** (3.2.2).

EXAMPLE 2 The specification of *Ra* 1,5 using a 2,5 mm filter for a surface is a special specification operator, because one of the **specification operations** (3.2.1), the cut-off length used in the filtration, is not a **default specification operation** (3.2.2).

3.3.8
actual specification operator
specification operator (3.3.3) derived from the actual specification given in the actual technical product documentation

NOTE 1 The standard or standards in accordance with which the actual specification operator is to be interpreted are identified explicitly or implicitly.

NOTE 2 An actual specification operator can be either a **complete specification operator** (3.3.4) or an **incomplete specification operator** (3.3.5).

NOTE 3 An actual specification operator can be either a **special specification operator** (3.3.7) or a **default specification operator** (3.3.6).

3.3.9
verification operator
ordered set of **verification operation(s)** (3.2.5)

NOTE 1 The verification operator is the metrological emulation of a **specification operator** (3.3.3) and is the basis for the measurement procedure.

NOTE 2 A verification operator might not be a perfect simulation of the given specification operator. In this case, the differences between the two will result in uncertainty contributors, which are part of the **measurement uncertainty** (3.4.2).

EXAMPLE The verification of a diameter specification for a shaft by using a two-point diameter association, measuring the shaft — with a micrometer, for instance — a defined number of times and comparing the results to the specification in accordance with a defined set of rules.

3.3.10
perfect verification operator
verification operator (3.3.9) based on a full set of **perfect verification operation(s)** (3.2.6) performed in the prescribed order

NOTE 1 The only **measurement uncertainty** (3.4.2) contributions from a perfect verification operator are from **metrological characteristic deviation**(s) (3.1.1) in the implementation of the operator.

NOTE 2 The purpose of calibration is generally to evaluate the magnitude of these **measurement uncertainty** (3.4.2) contributors originating from the measuring equipment.

EXAMPLE In accordance with ISO standards, the verification of the specification Ra 1,5 is

— partition (choice) of the required surface from the actual workpiece,

— partition of non-ideal lines by the physical positioning of the measuring instrument in multiple places,

— extraction of data from the surface with an instrument in accordance with the requirements of ISO 3274, using the evaluation length given in ISO 4288,

— filtration of data using a Gaussian filter with a cut-off wavelength determined by the rules in ISO 4288 and the corresponding stylus tip radius and sample spacing, and

— evaluation of Ra value as defined in ISO 4287 and ISO 4288 (16 % rule).

Since each of these operations is a perfect verification operation and they are performed in the order prescribed in the specification, this verification operator is a perfect verification operator.

3.3.11
simplified verification operator
verification operator (3.3.9) including one or more **simplified verification operation(s)** (3.2.7), or deviations from the prescribed order of operations, or both of these

NOTE 1 The **simplified verification operation(s)** (3.2.7), deviations in the order of operations, or both, cause **measurement uncertainty** (3.4.2) contributions additional to those from the **metrological characteristic deviation(s)** (3.1.1) in the implementation of the operator.

NOTE 2 The magnitude of these uncertainty contributions is also dependent on the geometrical characteristics (deviations of form and angularity) of the actual workpiece.

EXAMPLE 1 Applying ISO standards, the verification of the upper limit of the diameter of a shaft with the specification ∅ 30 ± 0,1 Ⓔ using a two-point diameter evaluation — for instance, by measuring the shaft with a micrometer — is a simplified verification operator, because the specification indicates the diameter of the minimum circumscribed cylinder of a shaft.

EXAMPLE 2 In accordance with ISO standards, a simplified verification operator for the specification *Ra* 1,5 would be

— partition (choice) of the required surface from the actual workpiece,

— partition of non-ideal lines by the physical positioning of the measuring instrument in multiple places,

— extraction of data from the surface with an instrument using a skid (this instrument being, however, not in accordance with ISO 3274), using the evaluation length given in ISO 4288,

— filtration of data using a Gaussian filter with a cut-off wavelength determined by the rules in ISO 4288 and the corresponding stylus tip radius and sample spacing, and

— evaluation of *Ra* value as defined in ISO 4287 and ISO 4288 (16 % rule).

Since not all of these operations are **perfect verification operation(s)** (3.2.6), this verification operator is a simplified verification operator, the reason being that the use of a surface-texture measuring instrument with a skid is not the extraction operation prescribed in the specification.

3.3.12
actual verification operator
ordered set of **actual verification operation(s)** (3.2.8)

NOTE 1 The **actual verification operator** may be chosen to be different from the required **perfect verification operator** (3.3.10). The divergence between the **perfect verification operator** (3.3.10) and the chosen **actual verification operator** is the **measurement uncertainty** (3.4.2) [sum of **method uncertainty** (3.4.5) and **implementation uncertainty** (3.4.6)], see 3.4.5, Note 1.

NOTE 2 When the actual specification operator is incomplete then see 3.3.5 Note 2 and 3.4.5 Note 1.

3.4 Terms related to uncertainty

3.4.1
uncertainty
parameter, associated with a stated value or a relation, that characterises the dispersion of the values that could reasonably be attributed to the stated value or relation

NOTE 1 A stated value in the GPS field may be a measurement result or a specification limit.

NOTE 2 A relation in the GPS field is normally the difference between the values yielded by two different **operator**(s) (3.3.1) for the same feature, e.g. a **specification operator** (3.3.3) and an **actual verification operator** (3.3.12).

NOTE 3 A relation in the GPS field can also be the difference between the value yielded by, for example, a specification operator and a value that correlates to the function of the feature/feature [the **functional operator** (3.3.2)].

NOTE 4 Uncertainty [**measurement uncertainty** (3.4.2), **specification uncertainty** (3.4.3), **correlation uncertainty** (3.4.4), etc.] quantified in the GPS-field is always in the meaning of expanded uncertainty according to ISO/TR 14253-2 and GUM.

3.4.2
measurement uncertainty
uncertainty of measurement
See VIM:1993, definition 3.9.

NOTE For the purposes of this part of ISO/TS 17450, measurement uncertainty is equal to the sum (in the sense of the word according to GUM) of the **method uncertainty** (3.4.5) and the **implementation uncertainty** (3.4.6).

EXAMPLE The **measurement uncertainty** for the verification of the upper limit of the specification ∅ 30 ± 0,1 Ⓔ for a shaft, when the verification is performed by measuring the shaft with a micrometer, is derived from the difference in values obtained by the micrometer [taking into account the imperfections in the micrometer's spindle — implementation uncertainty contributors — as well as the flatness and parallelism of its anvils] and the values obtained by measuring the diameter of the minimum circumscribed cylinder with a perfect instrument (method uncertainty contribution).

3.4.3
specification uncertainty
uncertainty (3.4.1) inherent in an **actual specification operator** (3.3.8) when applied to a real feature/feature

NOTE 1 Specification uncertainty is of the same nature as **measurement uncertainty** (3.4.2) and may — if relevant — be part of an uncertainty budget.

NOTE 2 The specification uncertainty quantifies the ambiguity in the **specification operator** (3.3.3).

NOTE 3 For the purposes of this part of ISO/TS 17450, specification uncertainty is considered as part of the **compliance uncertainty** (3.4.7).

NOTE 4 Specification uncertainty is a property related to the **actual specification operator** (3.3.8).

NOTE 5 The magnitude of the specification uncertainty is also dependent on the expected or actual variation of the geometrical characteristics (deviations of form and angularity) of workpieces.

EXAMPLE The specification uncertainty of step dimension 30 ± 0,1, which does not specify which association shall be used, is obtained from the range of values that can be obtained with different association criteria.

3.4.4
correlation uncertainty
uncertainty (3.4.1) arising from the difference between the **actual specification operator** (3.3.8) and the **functional operator** (3.3.2) that defines the intended function of the workpiece, expressed in the terms and units of the actual specification operator

NOTE 1 Correlation uncertainty is, if possible, expressed in numbers and units comparable to the specification given.

NOTE 2 Correlation uncertainty is usually not related to a single **GPS specification** (3.5.3). Usually it takes a number of single GPS specifications to simulate a function (e.g. size, form and surface texture for the same feature of the workpiece).

EXAMPLE Where the **functional operator** (3.3.2) for a shaft is the shaft's ability to run in a hole with a seal for 2 000 h without leaking, and the **specification operator** (3.3.3) is ∅ 30 h7 for the size of the shaft and *Ra* 1,5 using a 2,5 mm filter for the surface texture of the shaft, then the correlation uncertainty is derived from this specification's ability to ensure that

— a shaft complying with the specification will run for 2 000 h without leaking, and

— a shaft that does not comply with the specification will not run for 2 000 hours without leaking.

3.4.5
method uncertainty
uncertainty (3.4.1) arising from the differences between the **actual specification operator** (3.3.8), and the **actual verification operator** (3.3.12), disregarding the **metrological characteristic deviation(s)** (3.1.1) of the actual verification operator

NOTE 1 When an **incomplete specification operator** (3.3.5) is given as the actual specification operator, it is necessary to design and choose a **complete specification operator** (3.3.4), as allowed by the incomplete actual specification operator, by adding operations or parts of operations missing in the incomplete specification operator in order to establish the corresponding

perfect verification operator (3.3.10). Based on the knowledge of this perfect verification operator, the actual verification operator is chosen. The divergence between the perfect verification operator and the chosen actual verification operator is the **measurement uncertainty** (3.4.2) [sum of the method uncertainty and the **implementation uncertainty** (3.4.6)].

NOTE 2 The magnitude of the method uncertainty value indicates the level of divergence of the chosen **actual verification operator** (3.3.12) from the **perfect verification operator** (3.3.10).

NOTE 3 Even with perfect measuring equipment, it is impossible to reduce the **measurement uncertainty** (3.4.2) below the method uncertainty.

EXAMPLE If the specification for a shaft indicates ∅ 30 ± 0,1 Ⓔ, and a perfect micrometer (i.e. no scale error and perfectly flat and parallel anvils) is used to verify the upper limit of the specification, then the method uncertainty is derived from the difference in values obtained by the micrometer and the values obtained by measuring the diameter of the minimum circumscribed cylinder with a perfect instrument.

3.4.6
implementation uncertainty
uncertainty (3.4.1) arising from the divergence of the metrological characteristics of the **actual verification operator** (3.3.12) from the ideal metrological characteristics defined by the **perfect verification operator** (3.3.10)

NOTE 1 The purpose of calibration is generally to evaluate the magnitude of the part (implementation uncertainty) of the **measurement uncertainty** (3.4.2) originating from the measuring equipment.

NOTE 2 Other effects (e.g. environmental), not directly related to the measuring equipment, may also contribute to the implementation uncertainty.

EXAMPLE If the specification for a shaft indicates ∅ 30 ± 0,1 Ⓔ and a micrometer is used to verify the specification, then the implementation uncertainty is derived from the imperfections in the spindle of the micrometer, as well as the flatness and parallelism of its anvils only, regardless of whether it is the upper limit (specified as the diameter of the minimum circumscribed cylinder) or the lower limit (specified as the smallest two point diameter) that is being verified.

3.4.7
compliance uncertainty
sum (in the sense of the word according to GUM) of the **measurement uncertainty** (3.4.2) and **specification uncertainty** (3.4.3)

NOTE 1 The measurement uncertainty is equal to the sum of the **method uncertainty** (3.4.5) and the **implementation uncertainty** (3.4.6). Hence, the compliance uncertainty can also be expressed as the sum of the method uncertainty, implementation uncertainty and specification uncertainty.

NOTE 2 The compliance uncertainty quantifies the uncertainty with which it can be proven that a workpiece complies with all possible interpretations of a specification.

EXAMPLE If a specification for a sphere is S ∅ 30 ± 0,1, then this is an **incomplete specification operator** (3.3.5), since different association criteria may be used (this is because no default definition is, at the moment, given in ISO standards). The specification uncertainty is derived from the range of values that can be obtained when different association criteria (such as minimum circumscribed sphere, smallest two-point diameter, least squares sphere) are applied to data extracted from an actual workpiece (not perfectly spherical), because the specification does not prescribe which association criterion is to be used.

In order to obtain a **complete specification operator** (3.3.4) as the basis for the **perfect verification operator** (3.3.10), a particular association criterion and other missing parts of the complete specification operator have to be chosen. If a two-point association criterion is chosen as part of the complete specification operator, then the two-point association criterion is also part of the perfect verification operator.

If a micrometer is used to verify the specification, then there is practically no method uncertainty. However, there will be implementation uncertainty, which is derived from the imperfections in metrological characteristics of the micrometer — spindle errors, flatness and parallelism of its anvils etc.

In this example, the **measurement uncertainty** (3.4.2) consists of the implementation uncertainty only. Consequently, the compliance uncertainty consists of specification uncertainty and implementation uncertainty.

3.4.8
total uncertainty
sum (in the sense of the word according to GUM) of the **correlation uncertainty** (3.4.4), the **specification uncertainty** (3.4.3) and the **measurement uncertainty** (3.4.2)

NOTE The magnitude of the total uncertainty value indicates the level of divergence of the **actual verification operator** (3.3.12) from the **functional operator** (3.3.2).

EXAMPLE If the functional operator for a shaft is the ability of the shaft to run in a hole with a seal for 2 000 h without leaking, and the **specification operator** (3.3.3) is ∅ 30 h7 for the size of the shaft and *Ra* 1,5 using a 2,5 mm filter for the surface texture of the shaft, then the total uncertainty is derived from the ability to determine, based on measurements with, for instance, a surface texture instrument and a micrometer, whether

— a shaft measured as being in compliance with the specification will run for 2 000 h without leaking, and

— a shaft measured as not being in compliance with the specification will not run for 2 000 h without leaking.

3.5 Terms related to specifications

3.5.1
GPS specification element
standardized graphical symbol or symbols controlling an ordered set of one or more **specification operation(s)** (3.2.1)

NOTE 1 GPS specification elements are used in technical product documentation.

NOTE 2 Not all GPS characteristics have a full and sufficient list of GPS specification elements defined in the existing standards.

EXAMPLE In the surface texture specification: the symbology for USL, LSL, filter type, λs, λc, profile, parameter, number of sampling lengths, acceptance criteria, parameter value, manufacturing process, orientation of lay.

3.5.2
specification modifier
GPS specification element (3.5.1) that changes the default definition of the **basic GPS specification** (3.5.4), when applied

NOTE Specification modifiers may be defined by International Standards, national standards or by company standards/documents.

3.5.3
GPS specification
set of **GPS specification element(s)** (3.5.1) which, together, control a **specification operator** (3.3.3)

NOTE 1 A GPS specification can be expressed with or without **specification modifier(s)** (3.5.2).

NOTE 2 A GPS specification does not necessarily include a full and sufficient set of GPS specification elements.

3.5.4
basic GPS specification
shortest form for expressing a **GPS specification** (3.5.3) in technical product documentation

NOTE 1 When standardized by International Standards, basic GPS specifications are referred to as ISO basic GPS specifications. When defined by national or company standards, a similar specific reference is needed.

NOTE 2 A basic GPS specification is expressed without the application of **specification modifier(s)** (3.5.2).

NOTE 3 When the ISO basic GPS specification is used, the **default specification operator** (3.3.6) applies.[2)]

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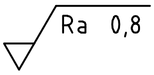
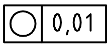
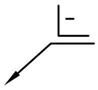
2) Many such operators are currently under development within ISO/TC 213.

EXAMPLE 1 ⌀30h7, ⌀38 ±0,1

EXAMPLE 2 

EXAMPLE 3 

EXAMPLE 4 

3.5.5
special GPS specification
GPS specification (3.5.3) expressed in technical product documentation, with the application of one or more **specification modifier(s)** (3.5.2)

NOTE In a special GPS specification, one or more **default specification operation(s)** (3.2.2) are overridden by a **special specification operation** (3.2.3) according to the indicated **GPS specification element**(s) (3.5.1).

3.5.6
actual GPS specification
GPS specification (3.5.3) defining a characteristic in the technical product documentation at hand

NOTE The actual specification can be a **basic GPS specification** (3.5.4) or a **special GPS specification** (3.5.5).

4 Basic tenets

The foundation of the GPS philosophy can be expressed in the four basic GPS tenets, A, B, C and D.

A It is possible to significantly control the function of a workpiece or feature using one or more GPS specifications in the technical product documentation.

NOTE There can be good or bad correlation between the workpiece or feature function and the GPS specifications used. In other words, the correlation uncertainty can be either small or large.

B A GPS specification for a GPS characteristic shall be stated in the technical product documentation. The workpiece or feature is to be considered acceptable/good when the specification is fulfilled. Only that which is explicitly required in the technical product documentation shall be taken into account. The actual GPS specification stated in the technical product documentation defines the measurand.

NOTE A GPS specification in the technical product documentation could be perfect/complete or imperfect/incomplete. In other words, the specification uncertainty can be anything from zero to very large.

C Realization of a GPS specification is independent of the GPS specification itself.

NOTE A GPS specification is realized in a verification operator. The GPS specification does not dictate which verification operators are acceptable. The acceptability of a verification operator is evaluated using the measuring uncertainty and, in some cases, the specification uncertainty.

D Standard GPS rules and definitions for verification define theoretically perfect means for proving the conformance or non-conformance of a workpiece/feature to a GPS specification (see ISO 14253-1). However, verification is always accomplished imperfectly.

NOTE Because verification involves the realization of the GPS specification in actual measuring equipment, which can never be made perfect, verification will always include implementation uncertainty.

5 Impact of uncertainty on basic tenets

5.1 Impact of correlation and specification uncertainties

A GPS specification is complete when all intended functions of the feature/feature are described and controlled with GPS characteristics. In most cases, the GPS specification will be incomplete because some functions are described/controlled imperfectly or not at all. Hence, there may be a good or bad connection between the feature/feature function and the GPS specifications used.

Correlation uncertainty refers to the case of imperfect control, while specification uncertainty implies absence of control. For example, a GPS specification with small correlation uncertainty and small specification uncertainty would completely describe and control geometric characteristics that tightly control the intended function. See Table 1 for a summary of the combinations that can result for these two uncertainties.

Table 1 — Combination of correlation and specification uncertainties

	Small specification uncertainty	Large specification uncertainty
Small correlation uncertainty	Describes and controls geometric characteristics that tightly control the intended function.	Geometric characteristics are described and controlled to achieve portions of the intended function but specification is incomplete.
Large correlation uncertainty	Describes all geometric characteristics but does not tightly control intended function.	Neither describes nor controls geometry required for intended function.

5.2 Impact of method and implementation uncertainties

Additionally, measurement uncertainty, which consists of method and implementation uncertainties, results with each practical (and imperfect) implementation of a GPS verification method. When the implemented procedure very faithfully mimics the theoretically exact definition, there is small measurement uncertainty.

NOTE A measurement of low measurement uncertainty is of little value when correlation or specification uncertainty, or both, is large.

Table 2 summarizes the combinations that can result for the method and implementation uncertainties.

Table 2 — Combination of method and implementation uncertainties

	Small implementation uncertainty	Large implementation uncertainty
Small method uncertainty	The measuring process closely follows the specification and is implemented with few deviations from ideal metrological characteristics.	The measuring process closely follows the specification, but is implemented with significant deviations from ideal metrological characteristics.
Large method uncertainty	The measuring process does not follow the specification very tightly, but it is implemented with few deviations from ideal metrological characteristics.	The measuring process does not follow the specification very tightly and it is implemented with significant deviations from ideal metrological characteristics.
NOTE It is impossible to tell *a priori* whether large method uncertainty and small implementation uncertainty or small method uncertainty and large implementation uncertainty will result in a higher overall measurement uncertainty. Small method uncertainty and large implementation uncertainty will generally appear as having a higher measurement uncertainty, as the implementation uncertainty is typically more visible than the method uncertainty.		

6 Specification process

The specification process is the first to take place. Its purpose is the translation of design intent into a requirement or requirements for specific GPS characteristics. The specification process is the responsibility of the designer, and comprises the following steps:

a) feature/feature function — the desired design intent of the GPS specification;

b) GPS specification — consisting of a number of GPS specification elements;

c) GPS specification elements — each of which controls one or more specification operations;

d) specification operations — organized in ordered sets to form a specification operator;

e) specification operator — correlates to a certain extent to the intended feature/feature function and defines the measurand of the specification.

7 Verification process

The verification process takes places after the specification process. Its purpose is the verification of the feature/feature characteristic to the specification operator defined by the actual GPS specification. This is done by implementation of the actual specification operator in an actual verification operator. The verification process is the responsibility of the metrologist, and comprises the following steps:

a) actual specification operator — can be broken down into an ordered set of actual specification operations and defines the measurand;

b) actual specification operations — each approximated by actual verification operations;

c) actual verification operations — grouped in an ordered set to form the actual verification operator;

d) actual verification operator — identical to the actual measurement process;

e) measured value — compared to the GPS specification.