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**Geometrical product specifications  
(GPS) — Inspection by measurement  
of workpieces and measuring  
equipment —**

Part 5:

**Uncertainty in verification testing of  
indicating measuring instruments**  
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*Spécification géométrique des produits (GPS) — Vérification par la  
mesure des pièces et des équipements de mesure —*

*Partie 5: Incertitude liée aux essais de vérification des appareils de  
mesure indicateurs*



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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 213, *Dimensional and geometrical product specifications and verifications*.

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ISO 14253 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment*:

- *Part 1: Decision rules for proving conformity or nonconformity with specifications*
- *Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification*
- *Part 3: Guidelines for achieving agreements on measurement uncertainty statements*
- *Part 4: Background on functional limits and specification limits in decision rules*
- *Part 5: Uncertainty in verification testing of indicating measuring instruments*
- *Part 6: Generalized decision rules for the acceptance and rejection of instruments and workpieces*  
[Technical Report]

## Introduction

This part of ISO 14253 belongs to the general geometrical product specification (GPS) series of documents (see ISO 14638). It influences chain link F of all chains of standards in the general GPS matrix.

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

For more detailed information about the relationship of this part of ISO 14253 to other standards and to the GPS matrix model, see [Annex B](#).

Decision rules for deciding conformity or non-conformity to specifications are based on the measurement uncertainty incurred while testing.

Usual practice in measurement familiarizes metrologists and practitioners with measurement uncertainty. Any possible effect that may affect the measurement result is considered and quantified as an uncertainty component and is eventually included in the combined uncertainty. The purpose of the measurement is to gather quantitative information on a given measurand, and the uncertainty statement expresses how reliable that information is.

In the case of tests of indicating measuring instruments, the purpose of the measurement is to investigate one or more metrological characteristics of the indicating measuring instrument rather than to measure characteristics of features of a workpiece. The uncertainty being evaluated in this case, the test value uncertainty, quantifies the accuracy of the test value. The test detects the quality of the indicating measuring instrument, reported through the test values and not through the test value uncertainty.

The test value uncertainty for indicating measuring instruments is not conceptually trivial to evaluate, and careful consideration is necessary to determine which uncertainty components should and which should not be accounted for.

Some tests of indicating measuring instruments may be relative to quantities other than instrument indications, or a single test may investigate both the instrument indication(s) and other metrological characteristics. An example is a test of a micrometer investigating the indication error (subject to an MPE) as well as the measuring force (subject to an MPL). For tests, or portions of them, relative to metrological characteristics other than instrument indications, this part of ISO 14253 is not applicable: they are about quantities for which the application of the ISO/IEC Guide 98-3 (GUM) and of the ISO 14253-2 is conceptually straightforward, with no need of further guidance in this part of ISO 14253.

A rigorous definition of the test value uncertainty when testing indicating measuring instruments is given. Application of conventional uncertainty evaluation based on this definition and according to the ISO/IEC Guide 98-3 (GUM) and the ISO 14253-2 determines which uncertainty components to account for.

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# Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment —

## Part 5: Uncertainty in verification testing of indicating measuring instruments

### 1 Scope

This part of ISO 14253 specifies concepts and terms for evaluating the uncertainties of the test values derived according to a test protocol agreed upon by the parties and relative to instrument indication(s), obtained in verification testing of GPS indicating measuring instruments.

**NOTE** The uncertainty of the test values, referred to as test value uncertainty, is not to be confused with the measurement uncertainty associated with using that indicating measuring instrument to measure workpieces. The former only is covered in this part of ISO 14253; for guidance on the latter see the ISO/IEC Guide 98-3 (GUM) and ISO 14253-2.

When a test of an indicating measuring instrument comprises several test values, some relative to the instrument indication and some to other metrological characteristics, this part of ISO 14253 is concerned with the uncertainty of the former only.

This part of ISO 14253 does not provide guidelines to ensure the adequacy of a test protocol; rather, once a test protocol is given, it describes how to evaluate the consequent test value uncertainty.

### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10360-1:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*

ISO 14253-1:2013, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformity or nonconformity with specifications*

ISO/TR 14253-6:2012, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 6: Generalized decision rules for the acceptance and rejection of instruments and workpieces*

ISO 14978:2006, *Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment*

ISO 17450-2:2012, *Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators, uncertainties and ambiguities*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

### 3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 10360-1, ISO 14253-1, ISO/TR 14253-6, ISO 14978, ISO 17450-2, ISO/IEC Guide 98-3 (GUM), ISO/IEC Guide 99 (VIM), and the following apply.

#### 3.1

##### test

<of a GPS indicating measuring instrument> sequence of preparatory, measurement, mathematical and decisional actions according to a test protocol

Note 1 to entry: Not all steps in the sequence are necessarily present in a test protocol.

Note 2 to entry: Tests are often used to verify the specifications of a GPS indicating measuring instrument.

Note 3 to entry: The specification of an indicating measuring instrument may be expressed by one or more MPEs (Maximum Permissible Errors).

Note 4 to entry: Prominent cases of tests are the acceptance test and the reverification test.

Note 5 to entry: This term is sometimes used in a wider sense, encompassing cases when a test produces a binary or categorical result. An example of a binary assessment is determining whether or not a software algorithm converged. For the purpose of this part of ISO 14253, tests are restricted to those based on test values.

Note 6 to entry: See [Figure 1](#).

#### 3.2

##### test instance

combination of test equipment, set up, measurement sequence, environmental and instrumental conditions of a test, which yields a test value(s)

#### 3.3

##### permissible test instance

test instance in compliance with the test protocol, and with the alternatives and stipulations therein

Note 1 to entry: An alternative occurs when the test protocol allows options, either discrete among enumerated cases, or continuous in a range of permissible values. An example of the former is the choice of the test equipment, e.g. a gauge block or a step gauge for testing a CMM; an example of the latter is the ambient temperature within the required test conditions.

Note 2 to entry: A stipulation occurs when the test protocol specifies the amount of measurement in a test, e.g. a specific number of repeated measurements.

Note 3 to entry: A test may be subject to alternatives and stipulations at the same time. For instance, test equipment is applied to an indicating measuring instrument in a limited number of configurations (stipulation) chosen at the tester counterpart's discretion (alternative).

Note 4 to entry: Alternatives serve two purposes. (1) To accommodate to actual conditions. For instance, alternative test equipment to accommodate actual availability, or any environmental condition within the required test conditions to accommodate the actual testing environment. (2) To leave details of the test unspecified up to the time of testing, to encourage the indicating measuring instrument manufacturer – in order to avoid non-acceptance of the instrument – to deliver overall compliant indicating measuring instruments. For instance, some procedural details may be left to the *tester counterpart* (3.14) to decide at the time of testing, to force the manufacturer to deliver a compliant indicating measuring instrument for any possible procedural option.

#### 3.4

##### test measurand

metrological characteristic of an indicating measuring instrument intended to be verified in a test, based on a single permissible test instance, defined by a test protocol

Note 1 to entry: A test protocol may allow for multiple permissible test instances, to adapt to actual circumstances and to limit the experimental effort. The test measurand is defined for each single test instance, and different permissible test instances may give raise to different test measurands.



### 3.5 test protocol

predefined detailed specification of a test which defines the test measurand, the required test conditions and a decision rule

Note 1 to entry: The test protocol is defined either by relevant standards or – when none is available – by the tester or the *tester counterpart* (3.14).

Note 2 to entry: The tester and the tester counterpart are to agree upon the test protocol prior to the test.

Note 3 to entry: A default decision rule is given in ISO 14253-1. See ISO/TR 14253-6 for guidance in defining alternative decision rules.

Note 4 to entry: An unambiguous test protocol is crucial for the effectiveness of a test. In particular, the definition of the set of permissible test instances constitutes a trade-off between thoroughness and practical and economical viability of the test.

Note 5 to entry: As the default rule in ISO 14253-1 is stringent and conservative, in this case the verification approaches a proof in an absolute sense.

### 3.6 measured test indication

result of a measurement performed in a test, which contributes to the test value according to a test operator

Note 1 to entry: A test value may be based either on a single or on multiple measured test indications, as stipulated in the test protocol.

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### 3.7 test operator

predefined sequence of mathematical and/or statistical operations applied to the measured test indication(s) collected in the test to deliver a test value

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Note 1 to entry: Each test value is delivered according to a test operator. In the case of a test yielding multiple test values (see 3.8 Note 4 to entry), as many test operators are needed.

Note 2 to entry: The operations in the sequence can be divided in four broad categories: outlier rejection, noise reduction, statistics, and other mathematical operations.

- Examples of outlier rejection: (1) discarding measured test indications above the 99th percentile of the measured test indications collected in the test; (2) when no more than 2 % of the measured test indications causes failure to meet the specification, repeating those measurement three times.
- Examples of noise reduction: (1) taking the median of repeated measurement values; (2) performing a (spatial) frequency analysis and discarding all wavelengths above a predefined threshold.
- Examples of statistics: taking (1) the mean or (2) the maximum of the absolute values of the measured test indications collected in the test.
- Examples of other mathematical operations: (1) computing a Gaussian (best-fit) sphere associated to the coordinates obtained as measured test indications, and the individual distances of each measured test indication to the sphere centre; (2) computing the mean of the measured test indications taken in a scan over a line.

### 3.8 test value

quantity value measured in a test estimating the magnitude of a test measurand

Note 1 to entry: A test value is based on the measured test indication(s) and is derived according to the test operator.

Note 2 to entry: A test value cannot usually capture the performance of an indicating measuring instrument in full, because is limited as regulated by the test protocol.

Note 3 to entry: A test value may be derived from several measured test indications, according to the test operator.

Note 4 to entry: A test may yield more than a test value. For example, a test may address several metrological characteristics of an indicating measuring instrument for which MPE's are set, resulting in as many test values.

Note 5 to entry: [Figure 1](#) depicts the case of a test with a single MPE. When more are present in a test, items 3 to 7 are repeated for each MPE.

Note 6 to entry: There may be cases when no MPE is set to compare with. Possible examples are when a dismissed indicating measuring instrument is being reintegrated, or when an MPE originally stated in the data sheet is being adapted to the actual requirements of a company prior to reverification testing. In these cases, items 5 to 7 are missing, and the test terminates with the determination of the test value(s).

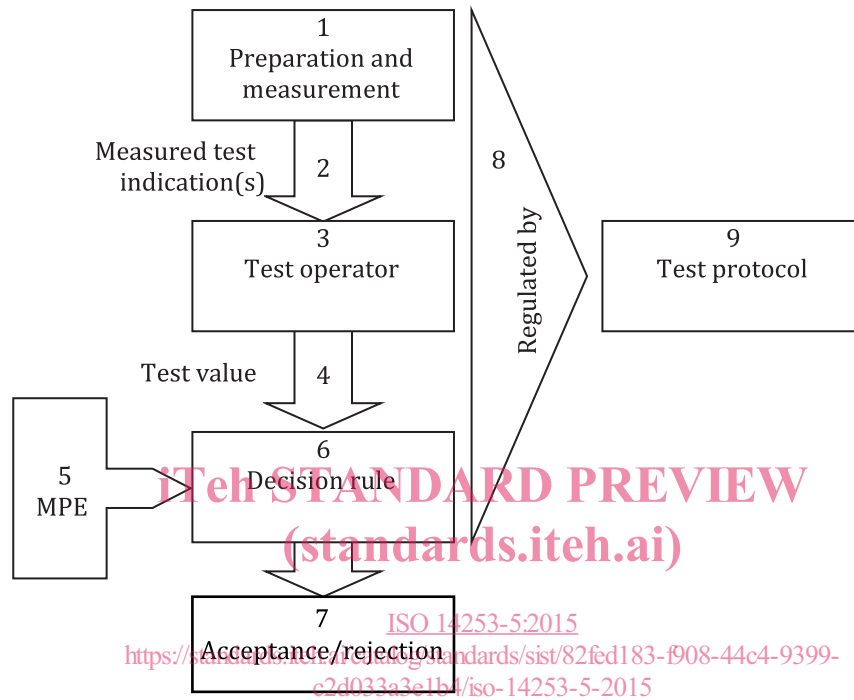


Figure 1 — Schematic of a test

3.9 test value uncertainty

test uncertainty  
measurement uncertainty associated to a test value

Note 1 to entry: The test value uncertainty is not a measure of the performance of the indicating measuring instrument under test; the performance is captured by the test values.

Note 2 to entry: The test value uncertainty is commonly used in the application of decision rules.

Note 3 to entry: The test value uncertainty is usually controlled by and is the responsibility of the tester, who usually provides and uses the test equipment. See 7.4 when alternative test equipment is provided by the *tester counterpart* (3.14).

Note 4 to entry: The test value uncertainty does not include any definitional uncertainty due to possible non uniqueness of test values in a permissible test instance. By agreement on the test protocol, the test is valid for any permissible test instance, for each of which a unique test measurand applies (see 3.4 Note 1 to entry).

Note 5 to entry: The test value uncertainty reveals neither the effectiveness of a test protocol in assessing a metrological characteristic, nor the reproducibility of a test value over different permissible test instances.

### 3.10 test equipment

measuring system and its accessories used in a test, other than the indicating measuring instruments under test and its recognized accessories

EXAMPLE 1 In the test of a micrometer, the test equipment may be a set of gauge blocks.

EXAMPLE 2 In the test of a CMM, the test equipment may be calibrated test lengths and a calibrated sphere with their supports.

### 3.11 instrument-related input quantity

input quantity affecting a test value, associated with the indicating measuring instrument

EXAMPLE 1 The distributed temperature – and its spatial and temporal gradients – of the indicating measuring instrument.

EXAMPLE 2 The distributed strain due to deformation of the indicating measuring instrument induced by the load of the test equipment weight.

### 3.12 test equipment-related input quantity

input quantity affecting a test value, associated with the test equipment

EXAMPLE 1 The distributed temperature – and its spatial and temporal gradients – of the test equipment.

EXAMPLE 2 Displacement of the test equipment relative to the indicating measuring instrument occurring during the test (drift and rock), and strain of the test equipment due to fixturing.

Note 1 to entry: While testing indicating measuring instruments, the usual roles in measurement of the indicating measuring instruments and of the workpieces are reversed (what measures what, see the Introduction). Typically, for workpiece measurements, a known accuracy indicating measuring instrument measures an unknown characteristic of the workpiece. But in this part of ISO 14253, known accuracy test equipment is used to measure test values of an unknown accuracy indicating measuring instrument. In light of this, the test equipment-related input quantities are influence quantities (see ISO/IEC Guide 99:2007, 2.52, EXAMPLE 3), while the instrument-related input quantities are not.

### 3.13 tester

party who performs a verification test

### 3.14 tester counterpart

party in a test other than the tester

Note 1 to entry: In an acceptance test, the tester counterpart may be either the customer or the supplier, possibly represented by a third party.

Note 2 to entry: In a reverification test, the tester counterpart is the user, possibly represented by a third party.

### 3.15 tester responsibility criterion

criterion according to which an input quantity is accounted for as a test value uncertainty component if and only if it is controlled by the tester, either directly or indirectly

Note 1 to entry: Examples of uncertainty components under the tester's direct control are the thermal stabilization and the set up of the test equipment.

Note 2 to entry: Examples of uncertainty components under the tester's indirect control are the calibration uncertainties of the test equipment: even if these values are determined by calibration laboratories and not by the tester, the tester controls them indirectly by selecting which equipment, when alternatives are allowed, and which calibration laboratory.