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Geometrical product specifications (GPS) — Dimensional measuring equipment —

Part 1: Design and metrological characteristics of callipers

Spécification géométrique des produits (GPS) — Équipement de mesurage dimensionnel —

Partie 1: Caractéristiques de conception et caractéristiques métrologiques des pieds à coulisse

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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).

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

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 13385-1:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— figures have been updated to show more modern technology;

— general design characteristics have been removed and reference to ISO 14978:2018 included;

— metrological characteristics have been clarified and modified;

— requirements for test methods have been included;

— default values for maximum permissible errors have been added.

A list of all parts in the ISO 13385 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences the chain links F and G of the chain of standards on size and distance in the general GPS matrix (see Annex C).

The ISO/GPS matrix model given in ISO 14638 gives an overview of the ISO/GPS system of which this document is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated; see ISO/TR 14253-6 for additional information on the selection of alternative decision rules.

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

Geometrical product specifications (GPS) — Dimensional measuring equipment —

Part 1:
Design and metrological characteristics of callipers

1 Scope

This document provides the most important design and metrological characteristics of callipers

— with analogue indication: vernier scale or circular scale (dial), and

— with digital indication: digital display.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO/TR 14253-6, *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 14978:2018, *Geometrical product specifications (GPS) — General concepts and requirements for GPS measuring equipment*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14978 and ISO/IEC Guide 99 and the following apply.

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

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

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

3.1
calliper
measuring instrument which evaluates a dimensional quantity of an internal or external feature on the basis of opposing contact from the movement of a slider with a measuring jaw, moving relative to a measuring scale on a rigid beam and to a fixed jaw

Note 1 to entry: See examples in Figures 1, 2 and 3.

Note 2 to entry: Callipers can be equipped for additional measurements, such as depth and step measurements (see Figures 1 and 2).

Note 3 to entry: The indication can be either analogue (vernier scale or circular scale) or digital.

3.2
measuring face contact
contact between the measuring face and an integral feature of a workpiece

3.2.1
full measuring face contact
contact between the full area of the measuring face and an integral feature of a workpiece

3.2.2
partial measuring face contact
contact between a partial area of the measuring face and an integral feature of a workpiece

3.2.3
measuring face line contact
contact between a line, nominally perpendicular to the length of the jaws, on the measuring face and an integral feature of a workpiece

4 Design characteristics

4.1 General design and nomenclature

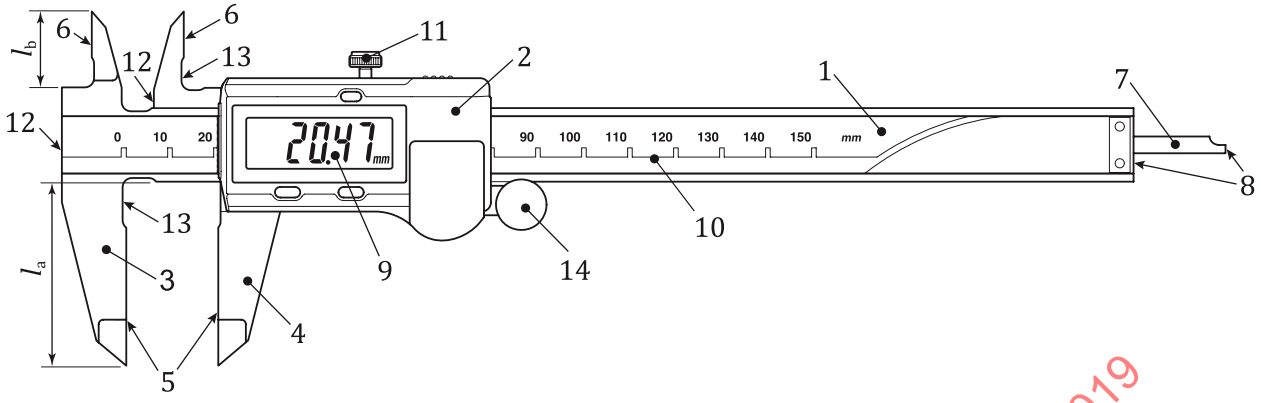
The design shall follow the general guidelines in ISO 14978, including the common design characteristics in ISO 14978:2018, Annex C. Examples of the general design of callipers are shown in Figures 1, 2 and 3.

The scale interval of the main scale on the beam of a calliper with a vernier scale shall be 1 mm. In the case of callipers with circular scales, the scale interval on the beam shall be either 1 mm or 2 mm.

4.2 Dimensions

The manufacturer shall state important calliper design dimensions, such as those shown in Table 1. The values shown in Table 1 are typical dimensions of the elements of callipers and are not requirements of this document. Table 1 does not include the length of the undercut, which is typically kept as small as practicable.

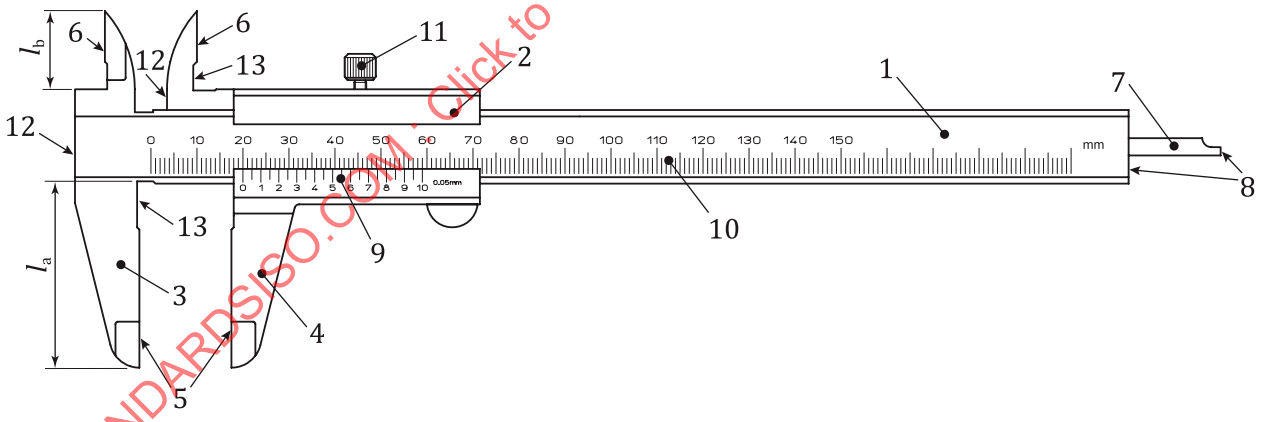
For callipers equipped with a depth measuring rod, the manufacturer shall state the cross-sectional dimensions of the rod, for example Ø 1,5 mm for round section or 1,2 mm × 3 mm for rectangular section.



Key

1 beam
2 slider
3 fixed (measuring) jaw
4 sliding (measuring) jaw
5 measuring faces for external measurements
6 measuring faces for internal measurements (crossed knife-edge faces)
7 depth measuring rod
8 measuring faces for depth measurement
9 digital display
10 main scale
11 locking screw
12 measuring faces for step measurement
13 undercut
14 thumb roller
l_a length of jaw for external measurements
l_b length of jaw for internal measurements

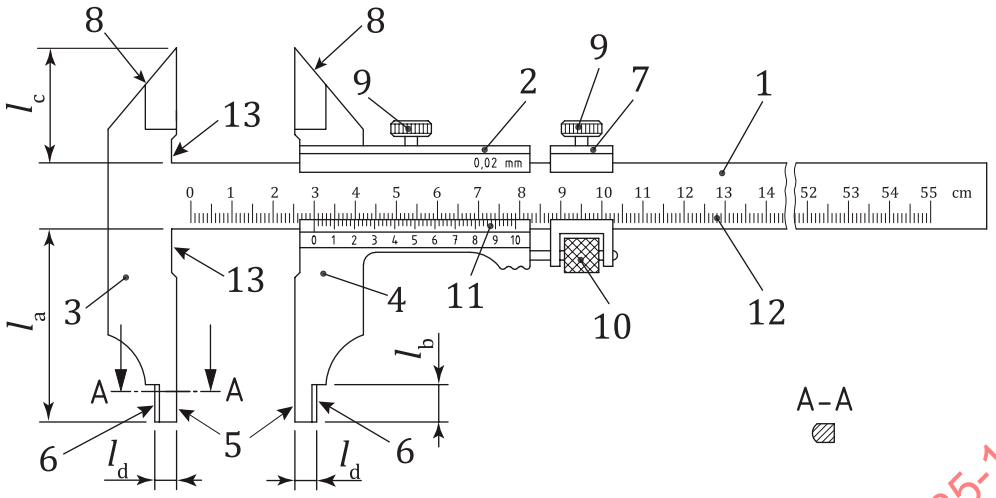
Figure 1 — Example design of callipers with digital display for external, internal, depth and step measurement



Key

1 beam
2 slider
3 fixed (measuring) jaw
4 sliding (measuring) jaw
5 measuring faces for external measurements
6 measuring faces for internal measurements (crossed knife-edge faces)
7 depth measuring rod
8 measuring faces for depth measurement
9 vernier scale
10 main scale
11 locking screw
12 measuring faces for step measurement
13 undercut
l_a length of jaw for external measurements
l_b length of jaw for internal measurements

Figure 2 — Example design of vernier callipers for external, internal, depth and step measurement



Key

1	beam	10	fine adjustment device
2	slider	11	vernier scale
3	fixed (measuring) jaw	12	main scale
4	sliding (measuring) jaw	13	undercut
5	measuring faces for external measurements	l_a	length of jaw for external measurements
6	measuring faces for internal measurements	l_b	length of jaw for internal measurements
7	fine adjustment clamp	l_c	length of knife-edge jaw for external measurements
8	knife edges for external measurements	l_d	width of measuring faces
9	locking screw		

Figure 3 — Example design of vernier callipers for external and internal measurements and with a fine adjustment device

Table 1 — Typical dimensions of callipers

Dimensions in millimetres

Measuring range less than or equal to	Lengths l_a, l_b and l_c of the jaws					Width l_d of the faces for internal measurement
	Calliper according to Figure 1 or 2		Calliper according to Figure 3			
	l_a	l_b	l_a	l_b	l_c	
150	40	8 to 20	50	8 to 10	25 to 35	5
200	40 to 50	8 to 25	60 to 80	8 to 10	25 to 35	5
300	60 to 65	10 to 30	70 to 100	10 to 12	35 to 45	5
500	70 to 95	15 to 40	100 to 150	15 to 20	50 to 60	5 or 10
750	70 to 95	15 to 40	100 to 150	15 to 20	50 to 60	5 or 10
1 000	100 to 130	20 to 60	125 to 150	20 to 30	50 to 60	10 to 20
1 500	100 to 130	20 to 60	150 to 200	20 to 30	50 to 60	10 to 20
2 000	100 to 130	20 to 60	150 to 200	20 to 30	50 to 60	10 to 20
NOTE The measuring range refers to external measurements for the callipers in Figures 1, 2 and 3.						

5 Metrological characteristics

5.1 General

The metrological characteristics and associated maximum permissible error (MPE) values apply to any indications permitted for use of the calliper as defined by the manufacturer and when used in accordance with the manufacturer's recommendations. The MPE values cannot be smaller than the digital step or the scale interval on the circular scale or vernier scale.

5.2 Rated operating conditions

The manufacturer shall state any rated operating conditions that apply to the MPE values. All MPE values apply at a rated operating condition for a temperature of 20 °C exactly, unless otherwise stated. Test values shall therefore be corrected to 20 °C to obtain the error of indication that the calliper would have produced had the test been performed at 20 °C. If temperature correction to 20 °C is not performed, this document allows the consequences to be included in the evaluation of the measurement uncertainty (see 6.2).

A calliper is a manually operated measuring instrument, and the user of the calliper is therefore necessarily included in the measuring system that is specified in accordance with this document. The user shall be reasonably skilled in the operation of the calliper.

5.3 Reference point

Callipers with a digital display or a circular scale shall have an adjustable zero point. Callipers with a digital display shall be able to be set to zero in any position within the measuring range; callipers with a circular scale shall be able to be set to zero within the range of the circular scale.

For callipers with an adjustable zero point, the metrological characteristics described in this document apply when the measuring faces for external measurements are properly brought into contact for zero setting, and therefore the reference point is considered fixed at this point when evaluating the metrological characteristics.

For callipers without an adjustable zero point, there can be an error when the external measuring faces are brought into contact with each other. This error shall be included in the evaluation of the metrological characteristics without applying any correction for it.

5.4 Test methods

The errors of indication shall be tested with suitable instruments or measurement standards with an appropriate measurement uncertainty, for example with gauge blocks according to ISO 3650, step gauges or setting ring gauges. When testing conformity to specification, sufficient testing shall be used to establish confidence in the results.

For acceptance testing, the customer is free to choose the test points; however, unless otherwise specified, the acceptance testing shall conform to the requirements in this document.

When considering test points, appropriate consideration shall be given to the calliper design and operating conditions that might indicate the presence of short-length cyclic or local errors. For callipers with circular scales or vernier scales, the chosen test points shall cover the range of the circular or vernier scale. For example, for callipers with circular scales, test points shall be chosen that orient the pointer at various angles within the circular scale.

5.5 Partial surface contact error, E (limited by E_{MPE})

The partial surface contact error is the error of indication when partial measuring face contact is employed to measure a measurement standard using the external measuring faces. This error

is calculated as the signed difference between the calliper indication and the reference value of the measurement standard.

The partial surface contact error shall be tested by measuring measurement standards at multiple test points located across the measuring range of the calliper (see Figure 4) and located on the external measuring faces at different distances away from the beam (see Figure 5).

The test points shall be distributed as evenly as practicable across the measuring range of the calliper with the minimum number of test points according to Table 2. At least one test point shall be at 90 % or greater of the measuring range. The reference point does not count towards satisfying the minimum test points in Table 2. Two test points, one near the beam and one near the tip of the jaws, shall be taken for both the longest and shortest measurement standards in the test for partial surface contact error (see Figure 5).

The averaging of multiple indications is not permitted when calculating the partial surface contact error. As such, the influence of repeatability is included in the test for partial surface contact error.

NOTE 1 The partial surface contact error is intended to detect a combination of calliper errors, including scale errors, the effect of the applied measuring force, the play between the beam and the slider, the deflection of the beam, and the influence of the parallelism and flatness of the external measuring faces.

NOTE 2 The partial surface contact error is influenced by the line contact error as discussed in Annex A.

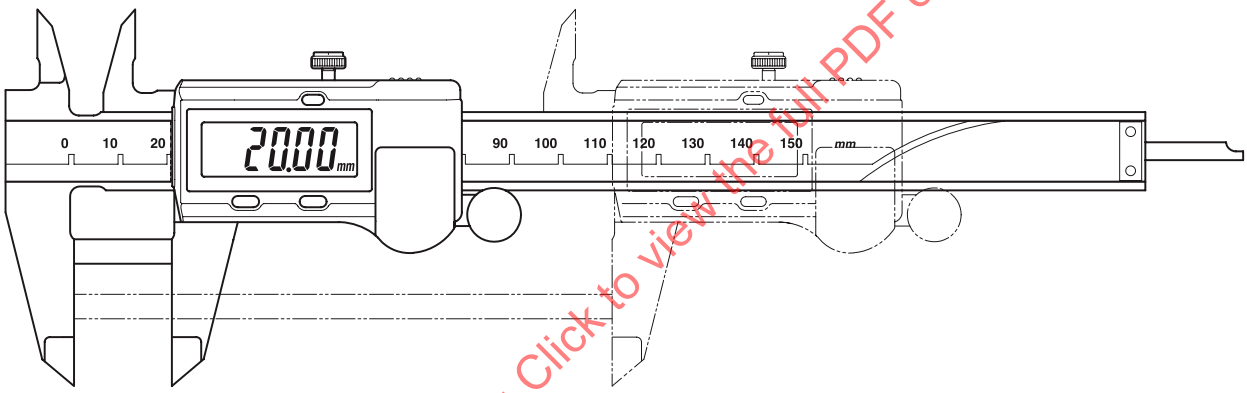


Figure 4 — Example of test arrangement for partial surface contact error showing two different test points located across the measuring range

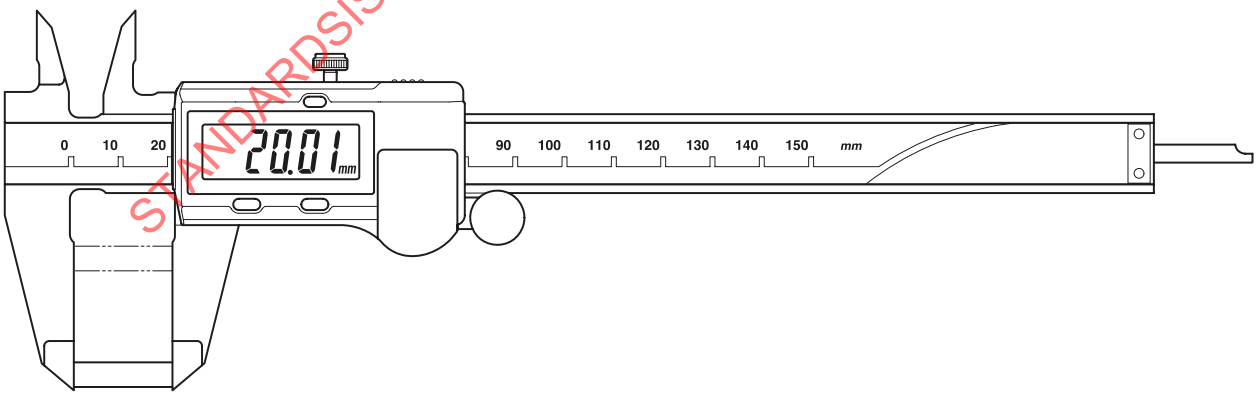


Figure 5 — Example of test arrangement for partial surface contact error showing the shortest measurement standard being measured both near the beam and near the tip of the jaws

Table 2 — Number of test points for partial surface contact error

Measuring range less than or equal to mm	Minimum number of test points
150	5
300	6
1 000	7
Over 1 000	8

5.6 Shift error, S (limited by S_{MPE})

5.6.1 General

The shift error is the error of indication when full or partial measuring face contact is employed for any measuring faces other than the external measuring faces. After zero setting with the external measuring faces as in 5.3, this error is calculated as the signed difference between the calliper indication and the reference value of a measurement standard when using any of the other measuring faces.

The applicability of the shift error depends on the design of the calliper. Typical shift errors include the use of internal measuring faces, depth measuring rod, and the step measuring faces.

Each of the types of measurement that the calliper is designed to perform shall be separately tested with at least one test point. For each, the shift error shall be tested by measuring an appropriate measurement standard.

5.6.2 Shift error — Internal measuring faces

For internal measuring faces, a setting ring gauge or other internal reference standard shall be used for testing (see Figure 6). The size of the measurement standard used to test for shift error when using the internal measuring faces shall be larger than 20 mm, with the default size being between 20 mm and 50 mm, unless a larger size is necessary due to the design of the calliper, for example due to the width of the faces for internal measurement as shown in Figure 3.

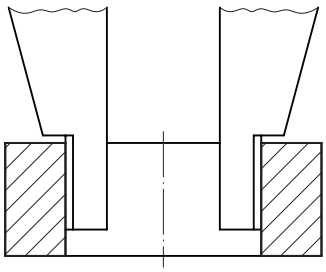
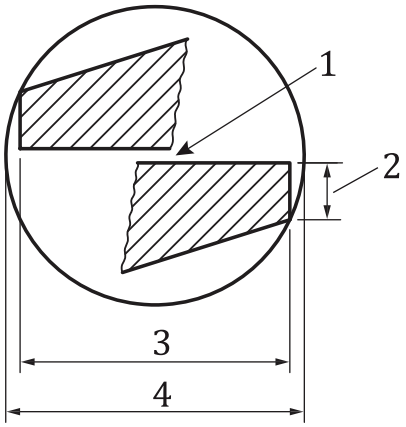


Figure 6 — Example of test arrangement for shift error — Internal measurement

5.6.3 Shift error — Crossed knife-edge internal measuring faces

For callipers which use crossed knife-edge internal measuring faces, an additional shift error can occur when measuring a small cylindrical internal diameter. The effect depends on the gap between the measuring faces and the thickness of the knife-edge faces (see Figure 7). Unless otherwise stated, this metrological characteristic applies to callipers with a measuring range less than or equal to 300 mm.

The shift error due to crossed knife-edge internal measuring faces shall be tested by measuring a small internal cylindrical measurement standard, for example a setting ring gauge, with a nominal size of 5 mm in diameter (see Figure 8).



Key

1 gap between the measuring faces
2 thickness of the knife-edge faces
3 indicated size
4 overall size

Figure 7 — Error due to crossed knife-edge internal measuring faces in small holes

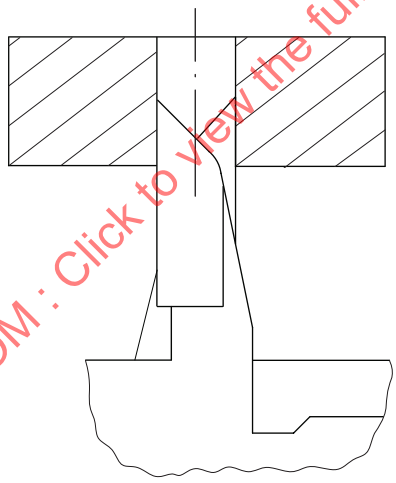


Figure 8 — Example of test arrangement for shift error — Internal measurement of 5 mm diameter using the crossed knife-edge internal measuring faces

5.6.4 Shift error — Depth or step measuring faces

For depth or step measuring faces, a gauge block and surface plate or other step height measurement standard shall be used for testing. By default, the size of the measurement standard used to test for shift error when using the depth or step measuring faces shall be less than 50 mm. See Figures 9 and 10.

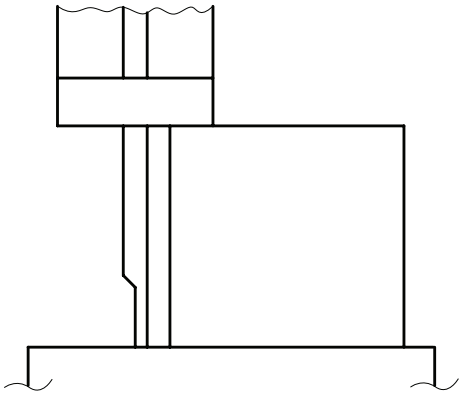


Figure 9 — Example of test arrangement for shift error — Depth measurement

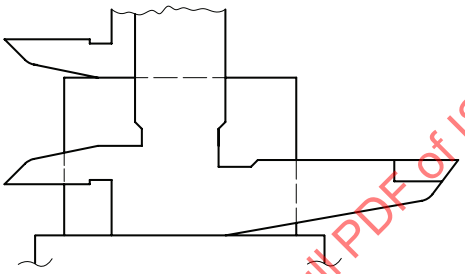


Figure 10 — Example of test arrangement for shift error — Step measurement

5.7 MPE values

For acceptance tests, MPE values shall be stated by the manufacturer in accordance with this document. Table 3 provides an example of a specification sheet with blanks to enter the MPE values. For reverification tests, the MPE values shall be stated by the user. This document is intended to be used by the manufacturer or user to state the MPE values. Annex B shall be used for situations when no MPE values are stated.

5.8 Special cases

For callipers equipped with more than one scale, for example two vernier scales, the MPE values apply to the use of the multiple scales. Testing shall be done across the measuring range of the calliper using each scale.

For callipers equipped with multiple external jaws, for example the calliper shown in Figure 3, the MPE values apply to all pairs of measuring faces for external measurement. One pair of the external jaws shall be tested for partial surface contact error, E, and the others for shift error, S.

6 Determination of conformity to specifications

6.1 General

All errors of indication shall conform with the specified MPE values.

6.2 Measurement uncertainty

Evaluation of measurement uncertainty shall be performed in accordance with ISO/IEC Guide 98-3. When determining conformity with specification, the measurement uncertainty associated with a

test value (the test value uncertainty) shall be evaluated in accordance with ISO 14253-5. Additional guidance is available in ISO 14978:2018, Annex D.

Uncertainty associated with the reference standards used in testing, as well as any uncertainty associated with temperature, shall generally be included as contributors to the measurement uncertainty. The test value uncertainty shall generally not include contributions from the errors of the calliper, such as the calliper repeatability or resolution.

As in 5.2, the user of the calliper shall be skilled in the operation of the calliper to properly determine conformity with specifications. As discussed in ISO 14253-5, when the user is sufficiently skilled, any variation in the test values associated with the skills of the user of the calliper is generally not included as a contributor to the measurement uncertainty.

6.3 Decision rule

When demonstrating conformity or non-conformity to specifications, the decision rule accompanying the specifications shall be followed. If no decision rule is stated with the specifications, and no special agreement is made between supplier and customer, then the default rule of ISO 14253-1 applies.

NOTE Information on the selection of an alternative decision rule can be found in ISO/TR 14253-6.

Table 3 — Example specification sheet for metrological characteristics

Measured length, l mm	**Maximum permissible error of indication**	
	E_{MPE} µm	S_{MPE} µm
$0 \le l \le 50$		
$50 < l \le 100$		
$100 < l \le 200$		
$200 < l \le 300$		
$300 < l \le 400$		
$400 < l \le 500$		
$500 < l \le 600$		
$600 < l \le 700$		
$700 < l \le 800$		
$800 < l \le 900$		
$900 < l \le 1\,000$		
Analogue scale interval or digital step: _____ mm		

7 Marking

Callipers shall be marked with durable serialised identification using unique alphanumeric identification to identify the individual measuring equipment.

NOTE For the calliper shown in Figure 3, the value of the width, l_d, can be indicated on the jaw for internal measurements.

Annex A
(informative)

Calibration guidelines for metrological characteristics

A.1 General

The calibration of a calliper should generally include the evaluation of the performance of the calliper within its measuring range.

In general, the calibration should include verification testing of all metrological characteristics across the measuring range in accordance with this document. Based on the intended use of the calliper, a task-related calibration should be taken into consideration.

EXAMPLE For a calliper that is intended to only be used for external diameter measurements, the testing of any metrological characteristics associated with shift error (see 5.6) can be considered unnecessary.

A.2 Line contact error

Line contact error is the error of indication when measuring face line contact is employed using a single measurement standard, for example a cylindrical measuring pin, at any position along the external measuring faces. Line contact error detects the effects of the parallelism of the external measuring faces as well as any flatness error or localized wear. The parallelism of the external measuring faces also influences the partial surface contact error, E. Line contact error is therefore important for used callipers for the detection of worn measuring faces but often not necessary for new callipers. It is usually not necessary to test the line contact error at more than one position within the measuring range.

Prior to testing for line contact error, it is recommended that the light gap between the external measuring faces when brought into close contact with each other is observed. Gaps of light can be useful in identifying potential problems associated with localized wear or parallelism of the measuring faces.

The line contact error is tested by measuring a small cylindrical measurement standard, for example a 15 mm diameter cylindrical measuring pin, at different positions along the entire external measuring faces, perpendicular to the plane of jaws (see Figure A.1). The line contact error is calculated as the range of the measured values. The MPE value for line contact error is equal to the range of E_{MPE}, i.e. if E_{MPE} = ±a then the MPE for line contact error is 2a.

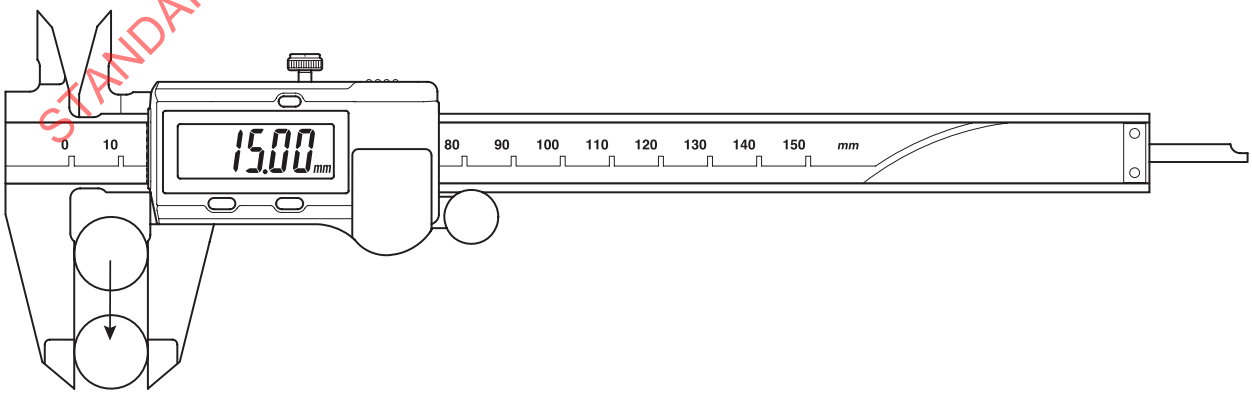


Figure A.1 — Example of test arrangement for line contact error