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Geometrical product specifications (GPS) — Dimensional measuring equipment —

Part 1: Callipers; Design and metrological characteristics

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

Partie 1: Pieds à coulisse; caractéristiques de conception et caractéristiques métrologiques

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 13385-1 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This first edition of ISO 13385-1, together with ISO 13385-2, cancels and replaces ISO 3599:1976 and ISO 6906:1984, which have been technically revised.

ISO 13385 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Dimensional measuring equipment*:

— *Part 1: Callipers; Design and metrological characteristics*

— *Part 2: Calliper depth gauges; Design and metrological characteristics*

Introduction

This part of ISO 13385 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain link 5 of the chains of standards on size and distance in the general GPS matrix.

The ISO/GPS Masterplan given in ISO/TR 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.

For more detailed information on the relation of this part of ISO 13385 to other standards and the GPS matrix model, see Annex G.

Geometrical product specifications (GPS) — Dimensional measuring equipment —

Part 1:
Callipers; Design and metrological characteristics

1 Scope

This part of ISO 13385 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 14253-2:2011, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 2: Guidance for the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification*

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

IEC 60529, *Degrees of protection by enclosures (IP Code)*

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, ISO/IEC Guide 99, and the following apply.

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

See Figures 1 and 2.

NOTE 1 Callipers with an additional measuring face at the end of the beam and a depth measuring rod are used for depth measurements (see Figure 1).

NOTE 2 The indication may be either analogue (vernier), circular scale or digital. Regarding digital data transfer, see 4.3.3.

NOTE 3 See Annex C for examples of different types of callipers.

NOTE 4 See Annex D for examples of several types of measurements.

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

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

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

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

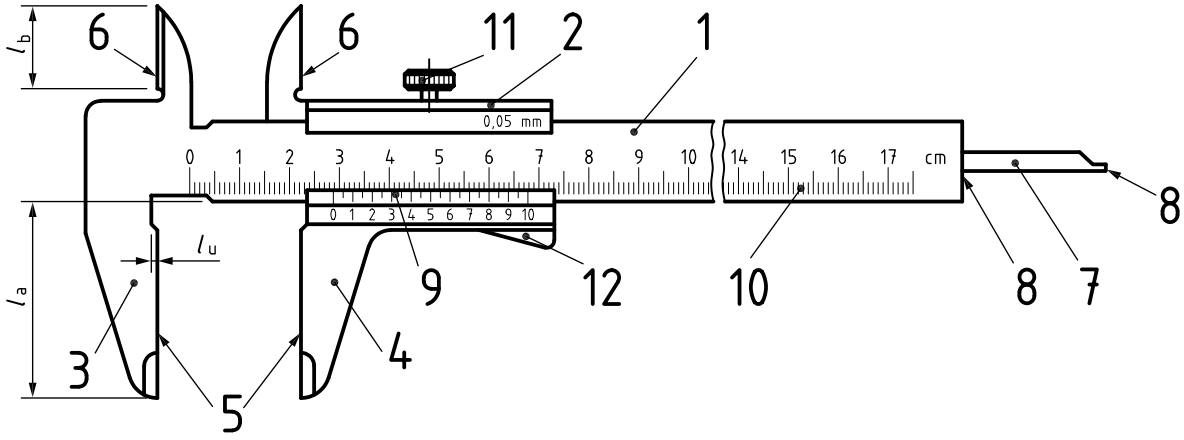
NOTE Form deviations in either the measuring face(s) or the feature are disregarded for the purposes of these definitions.

4 Design characteristics

4.1 General design and nomenclature

The general design and workmanship of the calliper shall be such that its metrological characteristics comply with this part of ISO 13385 under all operational orientations unless otherwise specified by the manufacturer.

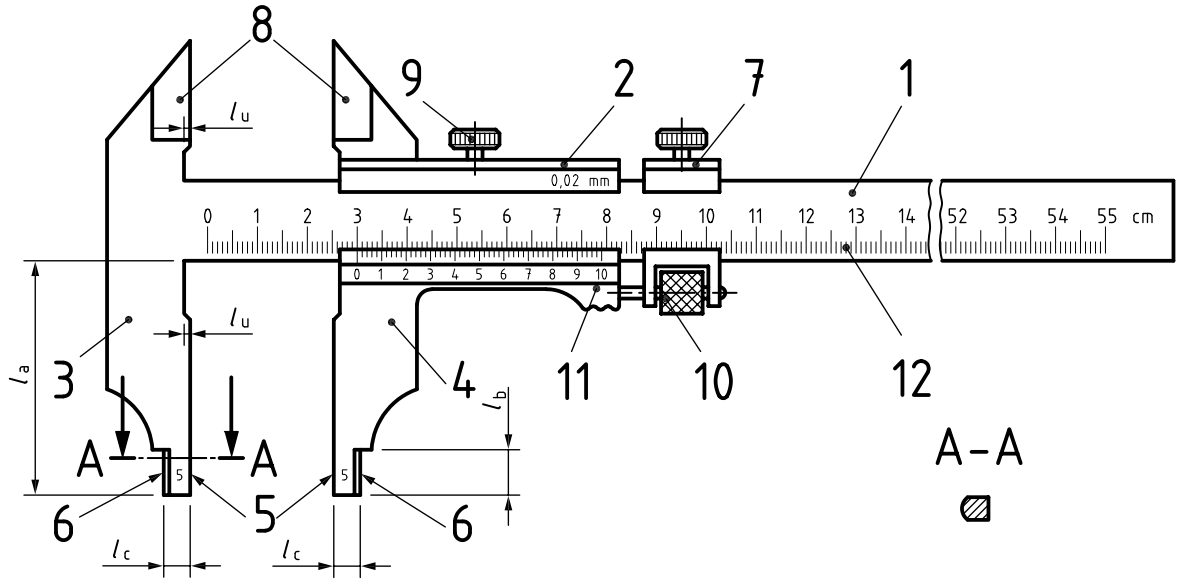
See Figures 1 and 2 for general design.



Key

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

Figure 1 — Example for a design of a calliper for external, internal and depth measurement (slider with locking screw or with clamping device)



Key

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

Figure 2 — Example for a design of callipers for external and internal measurement with a fine adjustment device

4.2 Dimensions

The dimensions of the elements which are given in Table 1 are typical dimensions.

Table 1 — Dimensions of callipers

Dimensions in millimetres

Measuring range up to	Lengths l_a and l_b of the jaws				Width l_c of the faces for internal measurement
	Calliper according to Figure 1		Calliper according to Figure 2		
	l_a	$l_{b,min}$	l_a	l_b	
150	40	up to 8	—	—	5
200	40 to 50	up to 8	60 to 80	8 to 10	5
250	—	—	70 to 85	10	5
300	60 to 65	up to 10	70 to 100	10	5
400	—	—	100 to 125	20	5 or 10
500	—	—	100 to 150	18 to 20	5 or 10
750	—	—	100 to 150	18 to 20	5 or 10
1 000	—	—	125 to 150	20	10
1 500	—	—	150 to 200	20	10 to 20
2 000	—	—	150 to 200	20	10 to 20

NOTE The measuring range given for the callipers in Figures 1 and 2 refers to the measurement of external dimensions.

The length of the undercut, l_u, is typically kept as small as practicable.

4.3 Types of indicating devices

4.3.1 General

Several types of indicating devices exist:

— analogue indicating devices with either a vernier scale or a circular scale (see Figures 3 and 8);

— digital indicating devices with a digital display (see Figure 9).

On callipers with an analogue indicating device, the scale interval and its unit shall be labelled.

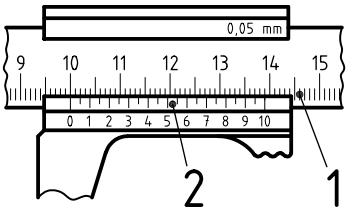
On callipers with a digital indicating device, the unit of the indication shall be labelled.

4.3.2 Analogue indicating devices

4.3.2.1 General

The scale interval of the main scale on the beam of a calliper with a vernier scale shall be 1 mm. The main scale shall be longer by at least one vernier scale length than the measuring range of the calliper. In the case of callipers with circular scales, the scale interval on the beam may be 1 mm or 2 mm (see Figure 8).

4.3.2.2 Main scale and vernier scale



Key

1 main scale

2 vernier scale

NOTE The actual reading in this figure is 100,00 mm.

Figure 3 — Example of analogue indicating device with vernier scale

4.3.2.3 Design of vernier scale

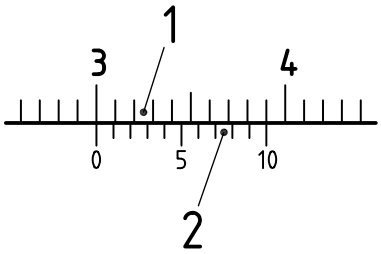
The graduating method of vernier scales is shown in Table 2.

Table 2 — Graduating methods of vernier scales

Dimensions in millimetres

Main scale interval	Graduating method of vernier scales	Nominal vernier scale interval	Explanatory figure
1	Divide 9 mm into 10 equal parts	0,1	Figure 4
1	Divide 19 mm into 10 equal parts	0,1	
1	Divide 19 mm into 20 equal parts	0,05	
1	Divide 39 mm into 20 equal parts	0,05	
1	Divide 49 mm into 50 equal parts	0,02	Figure 5

Examples of vernier scales with vernier intervals of 0,1 mm and 0,02 mm are shown in Figures 4 and 5.



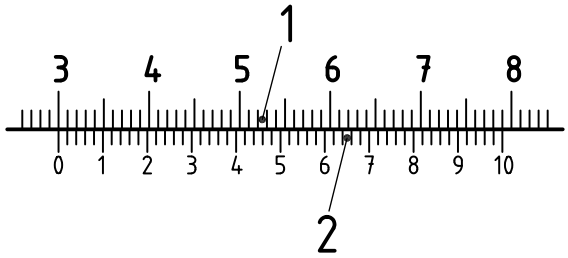
Key

1 main scale

2 vernier scale

NOTE The actual reading in this figure is 30,0 mm.

Figure 4 — 0,1 vernier scale of length 9 mm



Key

1 main scale

2 vernier scale

NOTE The actual reading in this figure is 30,00 mm.

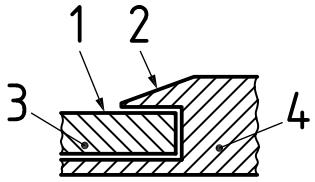
Figure 5 — 0,02 vernier scale of length 49 mm

4.3.2.4 Scale surface

For common types of scale surfaces, see Figures 6 and 7.

Key

1 main scale
2 vernier scale
3 beam
4 slider

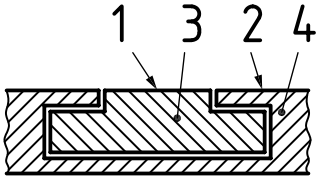


The height difference between the edges of the vernier scale surface and the main scale surface should be as small as practical.

Figure 6 — Standard slider with vernier scale

Key

1 main scale
2 vernier scale
3 beam
4 slider



The main scale surface and vernier scale surface shall be nominally at the same level and the distance between the main scale and the vernier scale should be as small as practical.

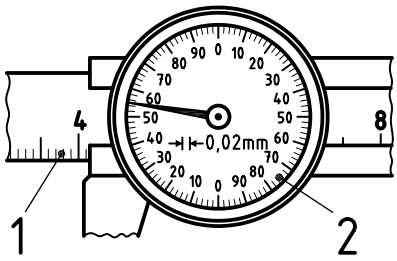
Figure 7 — Slider with vernier scale for readings without parallax error

4.3.2.5 Main scale and circular scale

The main scale is located on the beam and the circular scale is located on the slider. The circular scale shall be graduated in scale intervals. The scale interval and its unit shall be labelled.

Key

1 main scale
2 circular scale



NOTE The actual reading in this figure is 41,55 mm.

Figure 8 — Example of analogue indicating device with circular scale

4.3.3 Digital indicating devices

Key

1 electronic main scale
2 digital display

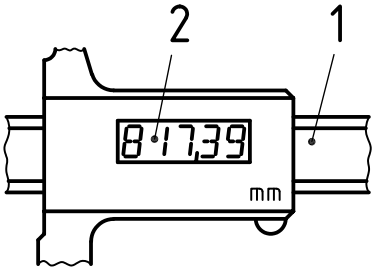


Figure 9 — Example of digital indicating device with digital display

Callipers with a digital display may also be capable of data transfer. In this case, the manufacturer shall describe the data output protocol (interface) in sufficient detail.

4.3.4 Protection for field use

Manufacturers shall express clearly which type of water and dust protection is provided (IP code according to IEC 60529), and whether electromagnetic field protection is given or not.

4.4 Measuring faces

Measuring faces shall consist of wear-resistant material of suitable surface finish. They shall not be sharp-edged.

5 Metrological characteristics

5.1 General

Callipers with a vernier scale have a fixed zero point.

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

The metrological characteristics of this part of ISO 13385 apply when the faces for external measurements are pressed against each other for zero setting.

NOTE Requirements for straightness, flatness and parallelism of the measuring faces are not given separately.

5.2 Effect of slider locking

If the slider is clamped (i.e. the slider is equipped with a locking screw or a clamping device), the dimension which is set shall not change and the indication shall fulfil the following conditions.

— Callipers with analogue indication: the indication shall not change.

— Callipers with digital indication: the indicated value shall not change by more than the last significant digit of the indication.

When the slider is locked, the digital display shall not change by more than one digital step.

5.3 Maximum permissible error of indication (limited by MPE)

5.3.1 General

The error-of-indication characteristics apply to any indications based on the zero setting stated in 5.1. These characteristics apply independently of the measuring range of the calliper. The error of indication shall not be greater than the maximum permissible error (MPE).

NOTE The limits of permissible error cannot be smaller than the digital step or the scale interval.

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

This is the error of indication when a partial measuring face contact (3.2.2) is employed. For an example, see A.2.2.

5.3.3 Repeatability of partial surface contact error, R (limited by R_{MPE})

This is the closeness of agreement between the results of successive measurements of the same measurand carried out at any position on the jaws under the same conditions of measurement. For an example, see A.2.6. The manufacturer shall express the manner in which the repeatability is assessed and reported.

5.3.4 Scale shift error, S (limited by S_{MPE})

This is the error of indication when using measuring faces other than the measuring faces for external measurement provided that a full contact of the measuring faces is given. For an example, see A.2.3.

NOTE Scale shift includes error of form of the measuring faces for depth measuring and change of the direction of measuring force.

5.3.5 Line contact error, L (limited by L_{MPE})

This is the error of indication when a measuring face line contact (3.2.3) is employed. For an example, see A.2.4.

NOTE Line contact error is especially important for used callipers.

5.3.6 Full surface contact error, J (limited by J_{MPE})

This is the error of indication when a full measuring face contact (3.2.1) is employed. For an example, see A.2.5.

NOTE The full surface contact error is a potential measure of the effect of the form deviation of both measuring faces.

5.3.7 Effect (error) due to crossed knife-edge distance, K (limited by K_{MPE})

This is the error of indication when the measurement is performed by using the crossed knife-edge jaws perpendicular to the length of jaws in a small cylindrical hole. For an example, see A.2.7.

5.4 MPE and MPL for a number of metrological characteristics

The maximum permissible error (MPE) is the extreme value of an error of a metrological characteristic permitted by the specification.

The maximum permissible limit (MPL) is the extreme value of a metrological characteristic permitted by the specification.

The manufacturer shall specify the MPE and MPL information for the calliper metrological characteristics listed in Figure 10. Unless otherwise specified by the manufacturer, the MPE/MPL values shall comply at any position within the measuring range and at any orientation of the calliper.

According to ISO 14978:2006, 7.5.1, MPEs shall be given as a continuous function (e.g. straight lines connecting given points); see ISO 14978:2006, 7.5.3, for the model. Figure 10 provides an example specification sheet for individual dimensions.

6 Indication in product documentation and data sheets

The indications shown in Table 3 are allowed for use in product documentation, drawings, data sheets, etc. as these alternatives reduce the amount of small text in subscripts to allow for improved visibility and clarity. An example data sheet is shown in Annex E.

Table 3 — Symbols and corresponding indications in product documentation, drawings, data sheets, etc.

Symbol used in this document	Corresponding indication
E_{MPE}	MPE_E
R_{MPE}	MPE_R
S_{MPE}	MPE_S
L_{MPE}	MPE_L
J_{MPE}	MPE_J
K_{MPE}	MPE_K

Nominal value	Maximum permissible error of indication Measuring force, scale interval or digital step	
	MPE_E	
mm	µm	
50		MPE_R ..... µm
100		MPE_S ..... µm
150		MPE_L ..... µm
200		MPE_J ..... µm
300		MPE_K ..... µm
400		
600		Scale interval ..... mm
800		Digital step ..... mm
1 000		
1 400		Maximum measuring force[a] ..... N
1 600		
2 000		

[a] Maximum force under which the MPEs apply; see also Annex B.

Figure 10 — Example of specification sheet for metrological characteristics

7 Proof of conformance with specifications

7.1 General

To prove conformance and non-conformance with specifications, apply ISO 14253-1. Uncertainty evaluation shall be performed according to ISO 14253-2 and ISO/IEC Guide 98-3.

7.2 Measurement standards for the calibration of metrological characteristics

Measurement standards shall be used in accordance with the applicable ISO standards.

8 Marking

Callipers shall be marked with serialized alphanumerical identification. For the calliper shown in Figure 2, the value of the width, l_c, shall be indicated on the jaw for internal measurements.

Any marking shall be easy to read and permanent and shall be placed on the surface of the calliper in a place that will not impair the metrological quality of the equipment.

Annex A
(informative)

Error tests

A.1 Test methods

The methods should evaluate the performance of the calliper throughout its measuring range.

The methods described below do not purport to be the only valid test methods, but their use is recommended.

A calibration curve provides the simplest means of evaluating the performance of the calliper under test (see ISO 14978).

A.2 Error of indication

A.2.1 General

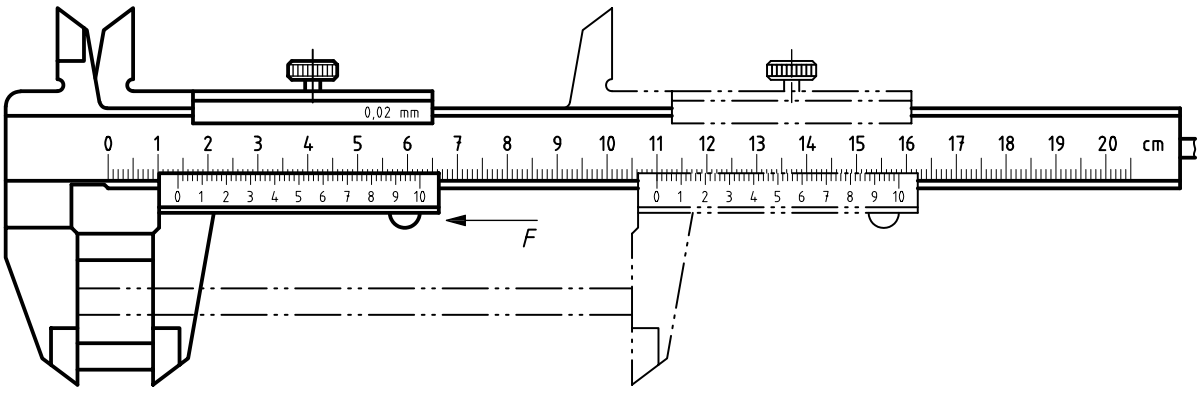
The error of indication may be tested with suitable instruments or measurement standards with an appropriate uncertainty, for example with gauge blocks according to ISO 3650, step blocks or setting ring gauges.

A.2.2 Partial surface contact error, E (limited by E_{MPE})

The partial surface contact error may be tested by measuring a measurement standard with small faces, e.g. gauge blocks, at different positions along the jaws, at any position within the measuring range (see Figure A.1). The difference between the indicated reading and the calibrated value of the measurement standard shall not exceed the MPEs specified according to ISO 14978:2006, 7.5.3, or given in the data sheet.

NOTE 1 The partial surface contact error depends on the usage of the calliper, e.g. the measuring position within the measuring range, the measuring range (deflection of the beam), the clearance between the slider and the beam and the length of the jaws.

NOTE 2 Parallelism and form deviation of the measuring surface of the jaws as well as scale errors are included.



Key

F maximum measuring force

Figure A.1 — Test arrangement for partial surface contact error

A.2.3 Repeatability of partial surface contact error, R (limited by R_{MPE})

The repeatability of partial surface contact error may be tested by measuring a measurement standard, e.g. gauge blocks, at any position on the measuring faces of the jaws and for any size (position within the measuring range). The repeatability evaluated according to ISO 14978 shall not exceed the MPE given in the data sheet.

A.2.4 Scale shift error, S (limited by S_{MPE})

The scale shift error may be tested by measuring a gauge block of, for example, 25 mm with the measuring faces for external measurement, then using a setting ring gauge of the same size with the measuring faces for internal measurement. The variation over two or more readings shall not exceed the MPE defined according to ISO 14978:2006, 7.5.3, or that given in the data sheet. This does not remove parallelism, which falls under a separate characteristic.

For a calliper with crossed knife edges, this test method may be performed by using a gauge block and a setting ring gauge of 10 mm.

To test the scale shift error, it is important to use a measurement standard, e.g. a gauge block and a setting ring gauge of the same size.

NOTE 1 The same test method may be used for testing the scale shift error between measuring faces for external measurements and the depth measuring rod.

NOTE 2 The diameter of the setting ring gauge for testing callipers with crossed knife edges shall not be less than 5 mm (see Figure A.3).

NOTE 3 It is not necessary to test the scale shift error in more than one position within the measuring range.

A.2.5 Line contact error, L (limited by L_{MPE})

The line contact error may be tested by measuring a cylindrical measurement standard, e.g. cylindrical measuring pins, of a small diameter (approximately 10 mm) at different positions along the jaws, perpendicular to the plane of jaws (see Figure A.2). The variation among two or more readings shall not exceed the MPEs given in the data sheet.

NOTE 1 The test of the line contact error is important for the detection of worn measuring faces of used callipers.

NOTE 2 It is not necessary to test the line contact error at more than one position within the measuring range.

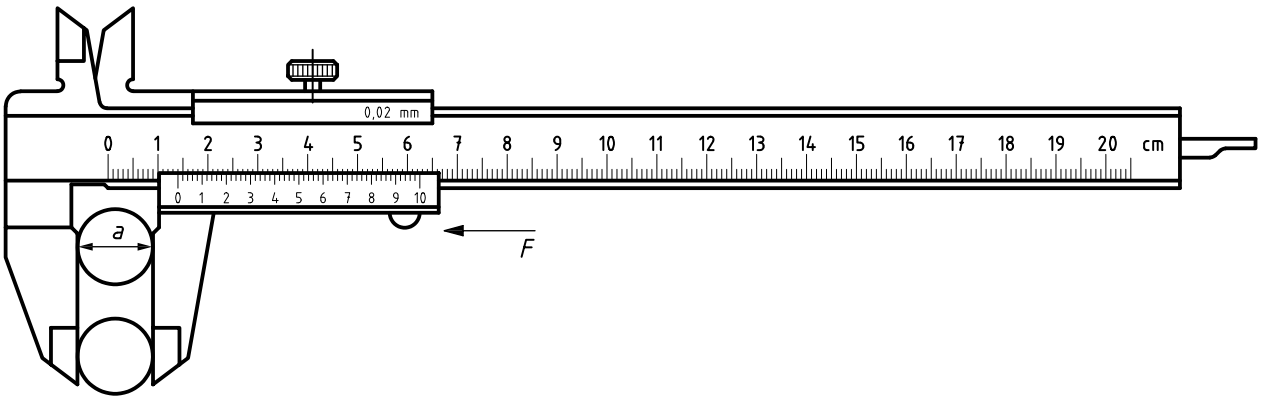


Figure A.2 — Test arrangement for line contact error

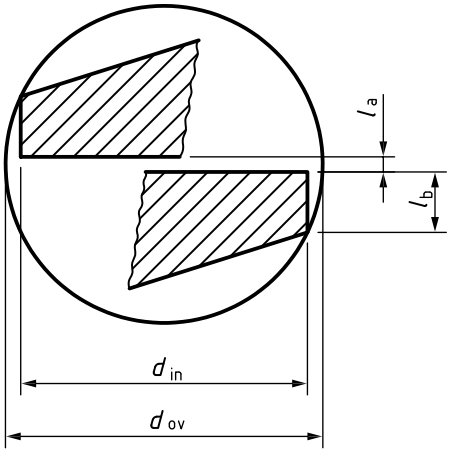
A.2.6 Full surface contact error, J (limited by J_{MPE})

The full contact error may be tested by measuring a measurement standard, e.g. gauge blocks, which covers the whole measuring surface of the jaws. The variation over two or more readings shall not exceed the MPEs given in the data sheet.

NOTE The full contact error is independent of the measuring range. It is sufficient to test the full contact error in one position within the measuring range.

A.2.7 Error due to crossed knife-edge distance, K (limited by K_{MPE})

The effect of the crossed knife-edge distance shall be tested by measuring a setting ring gauge not greater than 5 mm (the manufacturer shall state the size used in the test). The effect depends on the clearance between the measuring faces and the thickness of the knife-edge faces (see Figure A.3). The error of indication of the readings shall not exceed the MPEs given in the data sheet.



Key

l_a clearance
l_b thickness of the knife-edge faces
d_{in} indicated size
d_{ov} overall size

Figure A.3 — Error due to crossed knife edges in small holes

Annex B
(informative)

Advice on application

The calliper does not adhere to the conditions prescribed in the Abbe Principle. There is a tilt in the slider caused by the clearance fit between slider and beam as well as by the pressure of the movable measuring face against the part to be measured. This results in angular deviations that influence the measuring value and the error of indication. To reduce this influence, the workpiece should contact the measuring faces of the calliper as close as possible to the beam.

Temperature and deformation factors have a length-oriented influence. As a result, the smallest possible uncertainty of measurement is larger than the resolution of the measuring instrument. This has to be taken into consideration when evaluating the measured result. There are additional factors that contribute to the measuring uncertainty. For more details, see ISO 14253-2.

In the case of digital indications, pay attention to environmental factors, e.g. magnetic fields, electrical fields, dampness, etc., which could affect the functioning of the electronic components of the calliper.

Annex C
(informative)

Examples of different types of callipers

Figures C.1 to C.4 show different types of callipers.

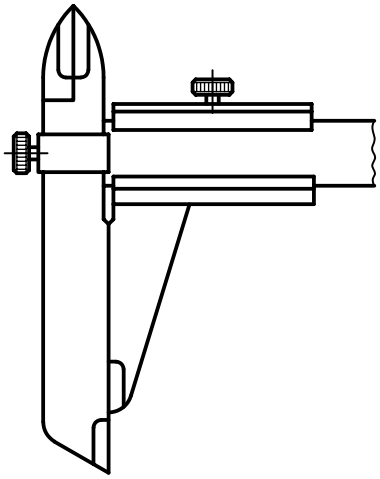


Figure C.1 — Type with an adjustable measuring jaw

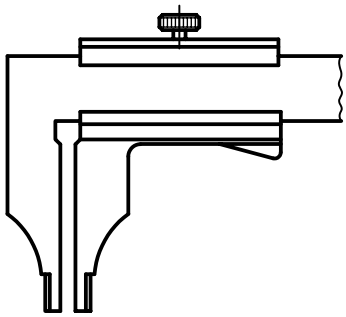


Figure C.2 — Basic type

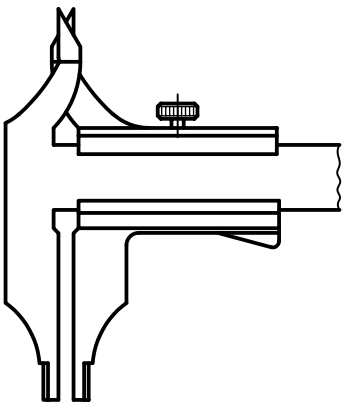


Figure C.3 — Type with internal measuring jaws (crossed knife-edge faces)

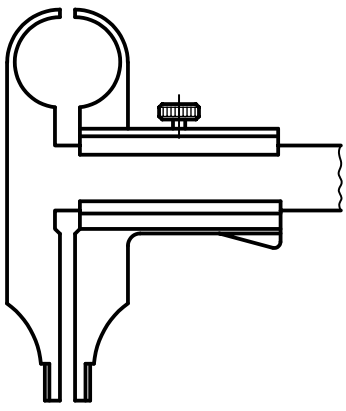


Figure C.4 — Type with half-round jaws

Annex D
(informative)

Examples of types of measurements

Figures D.1 to D.3 show different types of measurements.

Figure D.1 — External measurements

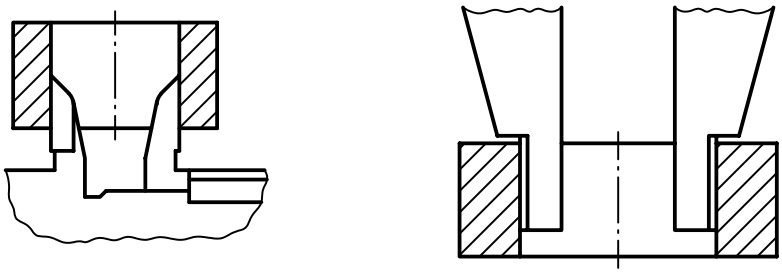


Figure D.2 — Internal measurements

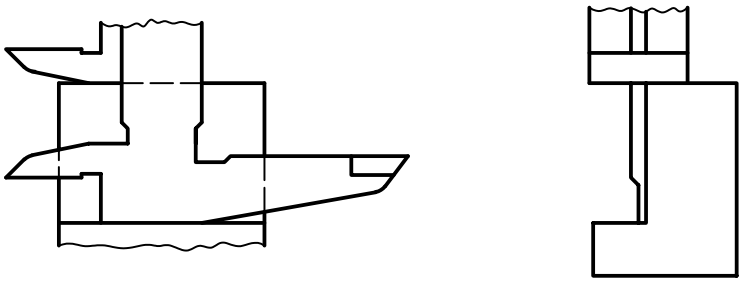


Figure D.3 — Step or depth measurements

Annex E
(informative)

Data sheet (example)

This data sheet is intended for communication between technical experts and the purchasing department of the same company.

Name of equipment .....

Detailed characteristics .....
(e.g. scale layout, clamping device, ...
fine-adjustment device, ...
IP protection, etc.) .....

Accessories: .....

Possible suppliers: .....

Delivery requirements: .....

Price range (optional): .....

Additional requirements .....
(e.g. inspection report, calibration certificate): .....

The design and metrological characteristics refer to the International Standard ISO 13385

Design characteristics

Measuring range: ..... mm

Measuring jaws: length a (l_a) ..... mm
length b (l_b) ..... mm
width c (b_c) ..... mm

Metrological characteristics

Scale interval/digital step: ..... mm

Repeatability (MPE_R) ..... µm

MPE_K ..... µm, calibrated with a ring gauge of diameter ..... mm

Errors (MPE) of indication

Nominal value mm	MPE_E µm	MPE_S µm	MPE_L µm	MPE_J µm

Organization: .....

Department: ..... Person responsible: .....

Date: .....

Annex F
(informative)

Calibration of metrological characteristics

The methods shall evaluate the performance of the calliper within its measuring range.

The global calibration at each scale point or at each digital step over the measuring range will necessitate a large number of readings. When it is considered that the intended use of the calliper does not warrant global calibration, partial calibration or task-related calibration should be taken into consideration.

For the determination of the errors of indication, a suitable number of intervals are necessary. These intervals are dependent on the scale interval or digital step and the measuring range used. Using these values, calibration curves with a fixed zero can be recorded (see ISO 14978:2006, Figure 5).

The MPE function for the characteristics can also be defined according to Figure 10 in ISO 14978:2006, or may be obtained from the specification sheet.

It is possible to perform a modified global calibration by using a suitable sampling technique, but this will result in an increase in the uncertainty of measurement.

Annex G
(informative)

Relation to the GPS matrix model

G.1 General

For full details on the GPS matrix model, see ISO/TR 14638.

The ISO/GPS Masterplan given in ISO/TR 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.

G.2 Information about this International Standard and its use

This part of ISO 13385 provides the most important design and metrological characteristics of callipers with vernier scale, circular scale (dial), and digital indication.

G.3 Position in the GPS matrix model

This part of ISO 13385 is a general GPS standard that influences chain link 5 of the chains of standards on size and distance in the general GPS matrix, as graphically illustrated in Figure G.1.

Fundamental GPS standards	Global GPS standards						
	General GPS standards						
	Chain link number	**1**	**2**	**3**	**4**	**5**	**6**
	Size						
	Distance						
	Radius						
	Angle						
	Form of a line independent of datum						
	Form of a line dependent on datum						
	Form of a surface independent of datum						
	Form of a surface dependent on datum						
	Orientation						
	Location						
	Circular run-out						
	Total run-out						
	Datums						
	Roughness profile						
	Waviness profile						
	Primary profile						
	Surface imperfections						
	Edges						

Figure G.1 — Position in the GPS matrix model

G.4 Related International Standards

The related International Standards are those of the chains of standards indicated in Figure G.1.

Bibliography

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

[2] ISO 3650:1998, *Geometrical Product Specification (GPS) — Length standards — Gauge blocks*

[3] ISO 8015, *Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules*

[4] ISO/TR 14638:1995, *Geometrical product specification (GPS) — Masterplan*

[5] ISO/TR 16015:2003, *Geometrical product specifications (GPS) — Systematic errors and contributions to measurement uncertainty of length measurement due to thermal influences*

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