INTERNATIONAL STANDARD

ISO 3650

Second edition
1998-12-15

Geometrical Product Specifications (GPS) — Length standards — Gauge blocks

Spécification géométrique des produits (GPS) — Étalons de longueur — Cales-étalons

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Contents

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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.

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.

International Standard ISO 3650 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 3650:1978), which has been technically revised.

Annexes A, B and C of this International Standard are for information only.

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Introduction

This International Standard is a geometrical product specification standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences chain link 6 (Calibration requirements — Calibration standards) of the chain of standards on size and distance.

For more detailed information on the relation of this standard to the GPS matrix model, see annex B.

Gauge blocks are length standards representing specified fractions of the unit of length, the metre, of the international system of units SI. Depending on the kind of application and the required quality, gauge blocks are offered in several grades. The calibration of the gauge blocks, i.e. the measurement of the length value at a specified point of the measuring face and the evaluation of the measurement uncertainty, is the basis for the application of gauge blocks as length standards.

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Geometrical Product Specifications (GPS) — Length standards — Gauge blocks

1 Scope

This International Standard specifies the most important design and metrological characteristics of gauge blocks with a rectangular cross section and a nominal length l_n ranging from 0,5 mm to 1000 mm.

Limit deviations and tolerances are stated for the calibration grade K and for the grades 0, 1 and 2 for various measuring purposes.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1:1975, *Standard reference temperature for industrial length measurements.*

ISO 1101:—[1)], *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Generalities, definitions, symbols, indication on drawings*.

ISO 6507-1:1997, *Metallic materials — Vickers hardness test — Part 1: Test method.*

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

International vocabulary of basic and general terms in metrology (VIM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 2nd edition, 1993.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 14253-1, VIM and the following apply.

3.1
gauge block
material measure of rectangular section, made of wear-resistant material, with one pair of planar, mutually parallel measuring faces, which can be wrung to the measuring faces of other gauge blocks to make composite assemblies, or to similarly finished surfaces of auxiliary plates for length measurements

[1)] To be published. (Revision of ISO 1101:1983)

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3.2
length of a gauge block
l
perpendicular distance between any particular point of the measuring face and the planar surface of an auxiliary plate of the same material and surface texture upon which the other measuring face has been wrung

See figure 1.

NOTES

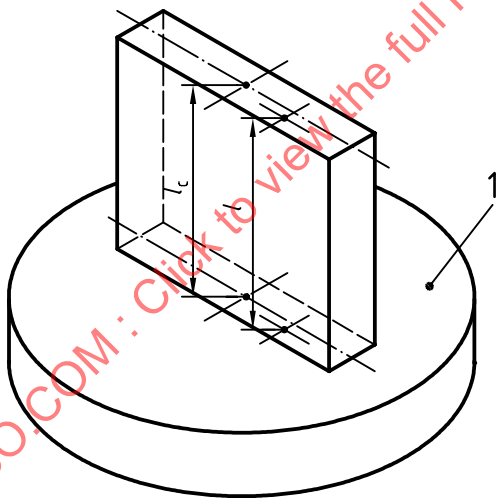
1 The length of a gauge block, l, includes the effect of one-face wringing (see 8.3.1).

2 The length, l, is a physical quantity consisting of a numerical value and a length unit (e.g. metre, millimetre or micrometre). If only the numerical value is treated (e.g. in tables), the units should be stated explicitly.

3.3
central length of a gauge block
l_c
length of a gauge block taken at the centre point of the free measuring face

See figure 1.

NOTE — Length l_c is a special instance of length l.



Key
1 Auxiliary plate

Figure 1 — Central length l_c and another example of length l at any point of a gauge block wrung to the plane surface of an auxiliary plate

3.4
deviation of the length at any point from nominal length
e
algebraic difference $l - l_n$

3.5
deviation from flatness
f_d
minimum distance between two parallel planes between which all points of the measuring face lie

See figure 2.

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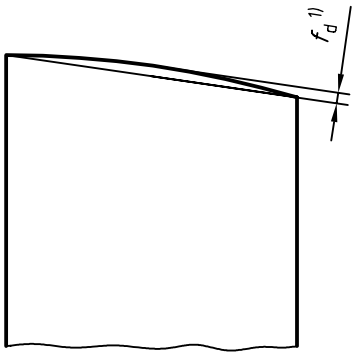


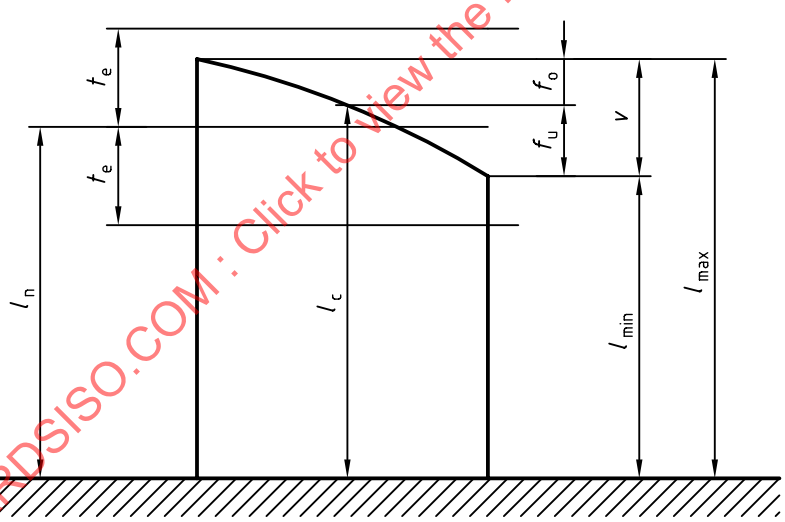
1) See 7.1.

Figure 2 — Deviation f_d from flatness

3.6
variation in length
v
difference between the maximum length l_{max} and the minimum length l_{min}

See figure 3.

NOTE — The variation in length is equal to the sum of the deviations f_o and f_u from the central length l_c.



NOTE — See table 4.

Figure 3 — Nominal length l_n; central length l_c; variation v with f_o and f_u; limit deviations t_e for the length at any point, proceeding from the nominal length

3.7
wringing
property of the measuring faces of gauge blocks to adhere to other measuring faces or to faces with similar surface finish as a result of molecular forces

4 Nomenclature of faces

See figure 4.

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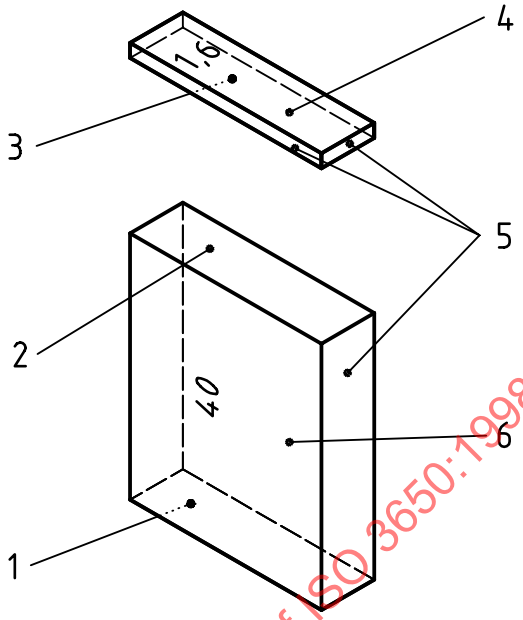
a) for nominal lengths l_n < 6 mm

b) for nominal lengths $l_n \geqslant 6$ mm



Key

1 Left hand measuring face
2 Right hand measuring face
3 Unmarked measuring face
4 Marked measuring face
5 Side faces
6 Marked side face

NOTE — For the complete marking, see 6.3.

Figure 4 — Nomenclature of faces

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5 Basis of measurement, traceability, reference condition

5.1 Unit of length: metre

The metre is defined as the length of the path travelled by light in vacuum in 1/299 792 458 of a second (17th General Conference of Weights and Measures, 1983).

The definition is realized by working wavelength standards recommended by the International Committee of Weights and Measures (CIPM).

5.2 Traceability of the length of a gauge block

The measured length of a gauge block is traceable to national or international length standards, if the measurement result can be related by an unbroken chain of comparison measurements each with stated uncertainties to a gauge block which has been calibrated by interferometry using appropriate wavelength standards.

5.3 Reference temperature and standard pressure

The nominal length and the measured lengths of a gauge block apply at the reference temperature of 20 °C (see ISO 1) and the standard pressure 101 325 Pa = 1,013 25 bar.

NOTE — The effect on the length of a gauge block caused by deviations from the standard pressure may be ignored under normal atmospheric conditions.

5.4 Reference orientation of gauge blocks

The length of a gauge block up to and including 100 mm nominal length refers to the vertical orientation with the measuring faces horizontal.

The length of a gauge block over 100 mm nominal length refers to the horizontal orientation with the block supported on one of the narrow side faces, without additional stress, by suitable supports each at a distance of 0,211 times the nominal length from the ends. When such a gauge block is measured by interferometry in horizontal orientation, the weight of the auxiliary plate wrung to one of the measuring faces shall be compensated.

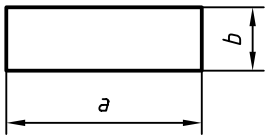
6 General dimensions, material properties, marking

6.1 General dimensions

The nominal dimensions of the cross section and their limit deviations are given in table 1.

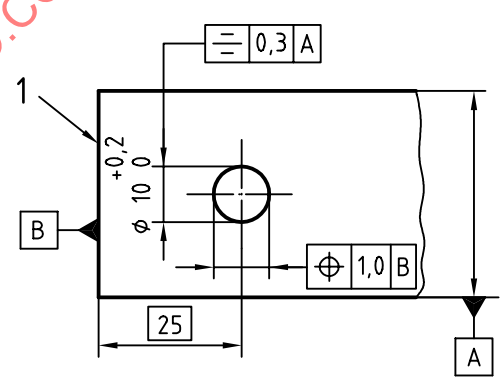
Table 1 — Cross section

Dimensions in millimetres

Cross section	Nominal length, l_n	a		b	
		nominal	limit deviation	nominal	limit deviation
	$0,5 \leqslant l_n \leqslant 10$	30	0 − 0,3	9	−0,05 −0,20
	$10 < l_n \leqslant 1000$	35			

If gauge blocks with nominal lengths over 100 mm are provided with coupling holes, the dimensions and location of holes shall be as shown in figure 5. Gauge blocks of grade K shall not be combined with coupling devices.

Dimensions in millimetres



Key

1 Measuring face

Figure 5 — Dimensions of coupling holes in mm

6.2 Material properties

6.2.1 Material

Gauge blocks shall be made of high grade steel or of other similarly wear-resistant material capable of being finished with surfaces that will wring readily, and which will be stable for length within the tolerances in table 2.

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6.2.2 Coefficient of thermal expansion

The coefficient of thermal expansion of steel gauge blocks in the temperature range 10 °C to 30 °C shall be $(11,5 \pm 1,0) \times 10^{-6}\ K^{-1}$.

The coefficient of expansion with its estimated uncertainty of determination shall be supplied with steel grade K gauge blocks, and also for all gauge blocks of all grades made of materials other than hardened steel.

6.2.3 Hardness

The measuring faces of steel gauge blocks shall have a Vickers hardness of not less than 800 HV 0,5 (see ISO 6507-1).

6.2.4 Dimensional stability

The maximum permissible changes in length per year of gauge blocks are stated in table 2. They apply when the gauge blocks are not exposed to exceptional temperatures, vibrations, shocks, magnetic fields or mechanical forces.

Table 2 — Dimensional stability

Grade	Maximum permissible change in length per year
K 0	$\pm (0,02\ \mu m + 0,25 \times 10^{-6} \times l_n)$
1 2	$\pm (0,05\ \mu m + 0,5 \times 10^{-6} \times l_n)$
NOTE — l_n is expressed in millimetres.	

6.3 Marking

Each gauge block shall be permanently marked with its nominal length in millimetres and shall be permanently and individually identifiable in characters not less than 1,5 mm high. Gauge blocks smaller than 6 mm nominal length may be marked on a measuring face, but an area of 9 mm × 12 mm at the centre of the measuring face and an area of 2,5 mm × 2,5 mm in each of the four corners shall be left clear of any marking.

If the grade is indicated on the gauge block, the following markings shall be used:

— calibration grade K: K

— grade 0: 0

— grade 1: –

— grade 2: =

Gauge blocks of nominal lengths greater than 100 mm shall bear marks located $0,211 \times l_n$ from the measuring faces, indicating the support positions (see 5.4).

7 Metrological requirements

7.1 General

Each gauge block shall conform to the requirements of its grade, as indicated below.

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Conformance with specifications shall be proved in accordance with ISO 14253-1.

The requirements of tables 3 and 4 applies to the measuring faces of the gauge block omitting a border zone with a maximum width of 0,8 mm as measured from the plane of the side faces. In this border zone the surface shall not lie above the plane of the measuring face.

Grade K blocks shall comply with the tolerance t_e for limit deviations from nominal length as grade 1. Very close tolerances for flatness and variation in length for grade K blocks are given in tables 3 and 4. These gauge blocks are intended for calibrating other gauge blocks and shall always be used in connection with a calibration certificate.

7.2 Flatness tolerance, t_f

7.2.1 Gauge blocks with nominal lengths exceeding 2,5 mm

The deviation f_d from flatness of each measuring face of a gauge block of nominal length greater than 2,5 mm shall not exceed the appropriate tolerance in table 3, whether the gauge block is wrung to an auxiliary plate or is in the unwrung state.

7.2.2 Gauge blocks with nominal lengths up to 2,5 mm

The deviation f_d from flatness of each measuring face of a gauge block of nominal length up to 2,5 mm shall not exceed the appropriate tolerance in table 3 when the gauge block is wrung to an auxiliary plate with a thickness of not less than 11 mm.

With the gauge block in the unwrung state, each measuring face shall be flat to within 4 µm.

Table 3 — Flatness tolerance t_f

Nominal length, l_n mm	**Flatness tolerance, t_f** µm			
	Grade			
	K	0	1	2
$0,5 \leqslant l_n \leqslant 150$	0,05	0,1	0,15	0,25
$150 < l_n \leqslant 500$	0,1	0,15	0,18	0,25
$500 < l_n \leqslant 1000$	0,15	0,18	0,2	0,25

7.3 Measuring faces

The measuring faces of all gauge blocks shall wring readily. Fine scratches without burrs may be accepted when they do not impair the wringing property.

The edges of the measuring faces shall be rounded to a radius not exceeding 0,3 mm or provided with a chamfer not exceeding 0,3 mm. The transition between the chamfer and the measuring face shall be such that the wringing property of the measuring faces is not impaired.

7.4 Side faces

7.4.1 Flatness

The flatness tolerance (see ISO 1101) of the side face is 40 µm for nominal lengths up to 100 mm.

For nominal lengths over 100 mm up to 1000 mm the flatness tolerances are given by

$$40\ \mu m + 40 \times 10^{-6} \times l_n$$

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7.4.2 Parallelism

The deviation from parallelism (see ISO 1101) of a side face with the opposing side face as a datum shall not exceed 80 µm for nominal lengths up to 100 mm.

For nominal lengths over 100 mm up to 1000 mm the parallelism tolerances are given by

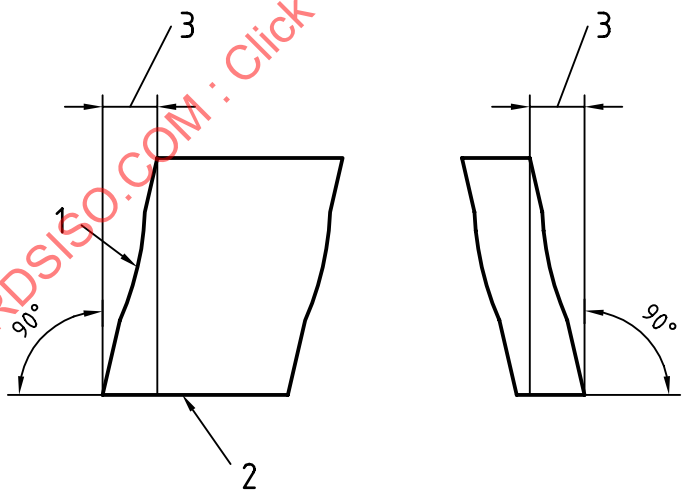
$$80\ \mu m + 80 \times 10^{-6} \times l_n$$

7.4.3 Perpendicularity

The perpendicularity tolerance (see ISO 1101) of a side face with a measuring face as a datum is given in table 4 (see figure 6).

Table 4 — Perpendicularity tolerance

Nominal length, l_n mm	Perpendicularity tolerance µm
$10 \leqslant l_n \leqslant 25$	50
$25 < l_n \leqslant 60$	70
$60 < l_n \leqslant 150$	100
$150 < l_n \leqslant 400$	140
$400 < l_n \leqslant 1000$	180



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Key

1 Side face
2 Measuring face
3 Deviation from perpendicularity

Figure 6 — Perpendicularity deviation of side faces with a measuring face as a datum

The angle between adjacent side faces shall be 90° ± 0°10'.

Table 5 — Limit deviation, t_e, of the length at any point of the measuring face from nominal length and tolerance, t_v, for the variation in length

Nominal length, l_n	Calibration grade K		Grade 0		Grade 1		Grade 2	
	limit deviation of length at any point from nominal length	tolerance for the variation in length	limit deviation of length at any point from nominal length	tolerance for the variation in length	limit deviation of length at any point from nominal length	tolerance for the variation in length	limit deviation of length at any point from nominal length	tolerance for the variation in length
	$\pm t_e$	t_v	$\pm t_e$	t_v	$\pm t_e$	t_v	$\pm t_e$	t_v
mm	µm	µm	µm	µm	µm	µm	µm	µm
$0,5 \leqslant l_n \leqslant 10$	0,2	0,05	0,12	0,1	0,2	0,16	0,45	0,3
$10 < l_n \leqslant 25$	0,3	0,05	0,14	0,1	0,3	0,16	0,6	0,3
$25 < l_n \leqslant 50$	0,4	0,06	0,2	0,1	0,4	0,18	0,8	0,3
$50 < l_n \leqslant 75$	0,5	0,06	0,25	0,12	0,5	0,18	1	0,35
$75 < l_n \leqslant 100$	0,6	0,07	0,3	0,12	0,6	0,2	1,2	0,35
$100 < l_n \leqslant 150$	0,8	0,08	0,4	0,14	0,8	0,2	1,6	0,4
$150 < l_n \leqslant 200$	1	0,09	0,5	0,16	1	0,25	2	0,4
$200 < l_n \leqslant 250$	1,2	0,1	0,6	0,16	1,2	0,25	2,4	0,45
$250 < l_n \leqslant 300$	1,4	0,1	0,7	0,18	1,4	0,25	2,8	0,5
$300 < l_n \leqslant 400$	1,8	0,12	0,9	0,2	1,8	0,3	3,6	0,5
$400 < l_n \leqslant 500$	2,2	0,14	1,1	0,25	2,2	0,35	4,4	0,6
$500 < l_n \leqslant 600$	2,6	0,16	1,3	0,25	2,6	0,4	5	0,7
$600 < l_n \leqslant 700$	3	0,18	1,5	0,3	3	0,45	6	0,7
$700 < l_n \leqslant 800$	3,4	0,2	1,7	0,3	3,4	0,5	6,5	0,8
$800 < l_n \leqslant 900$	3,8	0,2	1,9	0,35	3,8	0,5	7,5	0,9
$900 < l_n \leqslant 1000$	4,2	0,25	2	0,4	4,2	0,6	8	1

7.4.4 Edges

The edges between the side faces shall have a radius or chamfer of not greater than 0,3 mm.

8 Calibration of gauge blocks

8.1 General

Measurement of gauge blocks is outlined in 5.1 and 5.2 as a sequence starting from the basic definition of the unit of length and proceeding through the stage of interferometry for high grade (preferably K grade) gauge blocks. One or several further stages of measurement by comparison may follow for measurement of other grade gauges. More details of the stages are given in 8.3 and 8.4 respectively. The measurement result of length and the associated uncertainty shall be supplied in a calibration certificate.

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8.2 Wringing test

The wringing property of measuring faces of the gauge block is tested using an optical flat which shall satisfy a flatness tolerance of 0,1 µm.

The wrung measuring face shall be observed through the optical flat and shall be clear of interference bands, colour and bright spots.

For gauge blocks of grade 1 and 2 bright spots or shades are permitted to a minor extent.

8.3 Measurement by interferometry

8.3.1 Measured length

The length of a gauge block as shown in figure 1 (of grade K is recommended) shall be measured at the centre of the measuring face using the method of interferometry.

Measurement of the deviations f_o and f_u from the central length (see 3.6) shall be made at the points of maximum length l_{max} and minimum length l_{min} of the gauge block (see figure 3).

8.3.2 Auxiliary plate

The auxiliary plate upon which the gauge block is wrung during the measurement shall be in accordance with 3.2 and 6.2, i.e. it should consist of the same material as the gauge block and have a wringing surface of the same surface finish as the measuring faces of the gauge block. If auxiliary plates of some other material, such as crystalline quartz, are used, then the corrections made necessary by the different physical material properties need to be taken into account (see 8.3.3). The auxiliary plate shall be not less than 11 mm thick and shall have a wringing face with a flatness deviation less than 0,025 µm over a diameter of 40 mm.

8.3.3 Corrections to measurements by interferometry

Corrections shall be made to the calculations for significant influences; e.g.:

— temperature, atmospheric pressure and atmospheric humidity on the wavelength of light;

— deviation of temperature of the gauge block from 20 °C;

— the wringing action on the length of the gauge block when the gauge block and the auxiliary plate are of different materials;

— surface texture and optical phase changes on the reflection of the light wave;

— the aperture of the interferometer (diaphragm size and focal length) on the position of the interference fringes;

— compression of the gauge block over 100 mm when measured in vertical orientation.

8.3.4 Calibration certificate

The calibration certificate shall contain the measurement results, in particular the central length l_c or the deviation of central length from nominal $l_c - l_n$, the estimated uncertainties, and a statement of traceability with reference to the wavelength standards used. The certificate shall state which measuring face of the gauge block was wrung during the measurement and whether the gauge block was wrung in turn to the auxilliary by each of the two measuring faces. The calibration certificate shall also state the coefficient of thermal expansion used to adjust the results to lengths at 20 °C (see 8.3.3).

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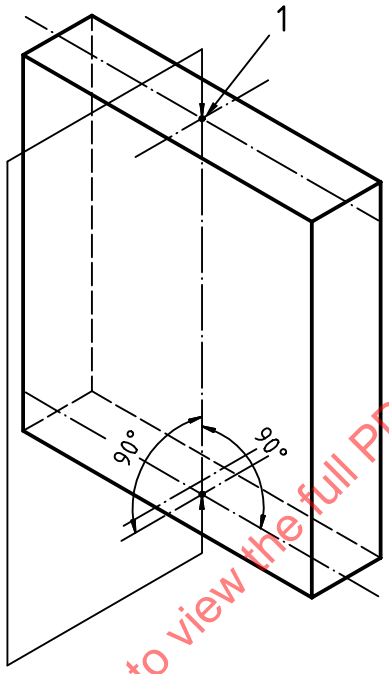
8.4 Measurement by comparison

8.4.1 Principle of measurement

In order to determine the length of a gauge block by comparison, the difference of its central length from that of a reference gauge block is measured and applied algebraically to the length of the reference. For the probing, the measuring faces of each gauge are touched from opposite directions as shown in figure 7, and the length difference is measured by a high resolution length indicator.



Key

1 Centre point

Figure 7 — Measurement of central length by comparison taking the perpendicular distance from the centre of a measuring face to the opposite one

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8.4.2 Central length

A measurement by comparison transfers the central length of a standard gauge block to a gauge block under test. The reference gauge block may either directly be measured by interferometry or related through one or several stages by comparison to a reference gauge measured by interferometry.

NOTE — The effect of one wringing, which is included in the length of the reference gauge block measured by interferometry, is transferred by the comparison measurement.

8.4.3 Method of determining length by comparison

The relatively small difference in central length between a reference gauge block of known central length and another gauge of unknown central length is measured by a high resolution length indicator (see annex A).

8.4.4 Variation in length

The measurement by comparison may be used to explore the variation in length. The variations between readings at the centre and at the four corners of the measuring face approximately 1,5 mm from the side faces could be regarded as representative for determining the variation in length. If representative points other than near the corners of the measuring face are used for the determination of the variation in length, their position shall be described.