
**Geometrical product specifications
(GPS) — Dimensional measuring
equipment; Height gauges — Design and
metrological characteristics**

*Spécification géométrique des produits (GPS) — Équipement de
mesurage dimensionnel; Mesureurs verticaux — Caractéristiques de
conception et caractéristiques métrologiques*





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Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Design characteristics	2
4.1 General design and nomenclature	2
4.2 Main dimensions	5
4.3 Types of indicating devices	6
4.4 Protection for field use	10
4.5 Measuring and scribing stylus	10
4.6 Instrument base	10
4.7 Design characteristics (manufacturer's specification)	10
5 Metrological characteristics	11
5.1 General	11
5.2 Operating conditions	11
5.3 Effect of slider locking	11
5.4 Definition of metrological characteristics (limited by MPE)	11
6 Proving of conformance with specifications	12
6.1 General	12
6.2 Measurement standards for the calibration of metrological characteristics	12
7 Marking	12
Annex A (informative) Error tests	14
Annex B (informative) Data sheet (Example)	19
Annex C (informative) Calibration of metrological characteristics	20
Annex D (informative) Relation to the GPS matrix model	21
Bibliography	23

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 13225 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

Introduction

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

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 of the relation of this International Standard to the GPS matrix model, see Annex D.

This International Standard is intended to serve the purpose of promoting

- the relationship between the manufacturer and purchaser, and
- the management of measuring instruments in the quality-assurance system.

Geometrical product specifications (GPS) — Dimensional measuring equipment; Height gauges — Design and metrological characteristics

1 Scope

This International Standard specifies the most important design and metrological characteristics of height gauges (with analogue indication or digital indication) for linear-dimensional measurements perpendicular to a surface plate.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the cited editions apply. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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, *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 provided 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 height gauge

measuring instrument in which a slider with a measuring stylus moves relative to a measuring scale on a beam and in which this motion is along a single vertical axis nominally perpendicular to a reference plane on the instrument base

NOTE 1 Height gauges are designed to be used with surface plates in which the reference plane of the height gauge is placed in contact with the surface plate.

NOTE 2 Various types of measuring scales on the beam with appropriate indication are possible, such as analogue indication, including vernier and circular scales, and digital indication.

NOTE 3 Most height gauges are capable of using various types of measuring styli, including a scriber.

NOTE 4 Height gauges are sometimes equipped with motorized motion of the slider, while on others the slider can only be moved by hand (manually).

NOTE 5 Height gauges are sometimes equipped with a device to control the measuring force.

NOTE 6 Height gauges are sometimes designed only for measuring distances parallel to the beam while others have measuring devices which allow for more complex measurements, including scanning functions and measurements perpendicular to the beam.

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

4 Design characteristics

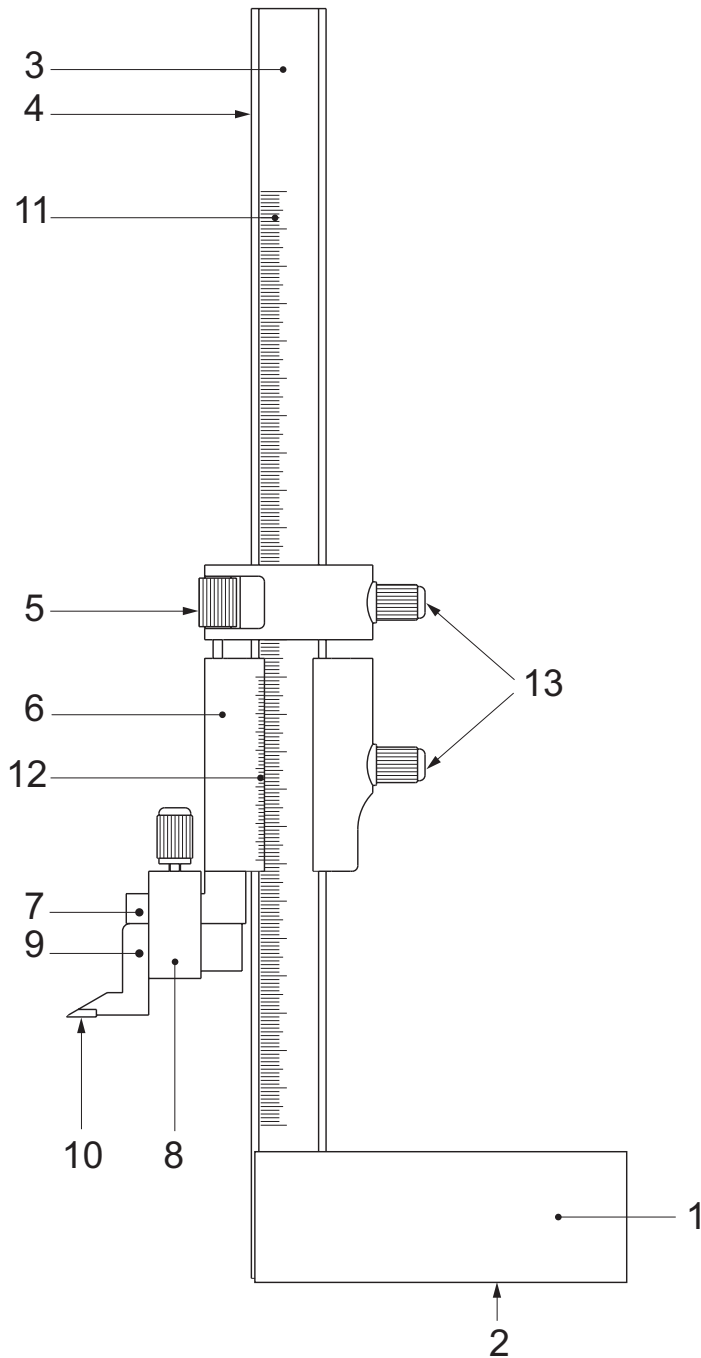
4.1 General design and nomenclature

The general design and workmanship of the height gauge shall be such that its metrological characteristics comply with the requirements of this International Standard, unless otherwise specified by the manufacturer.

The height gauge can be manually moved on a surface plate. Between the height gauge and surface plate there may be

- mechanical contact, or
- an air bearing system.

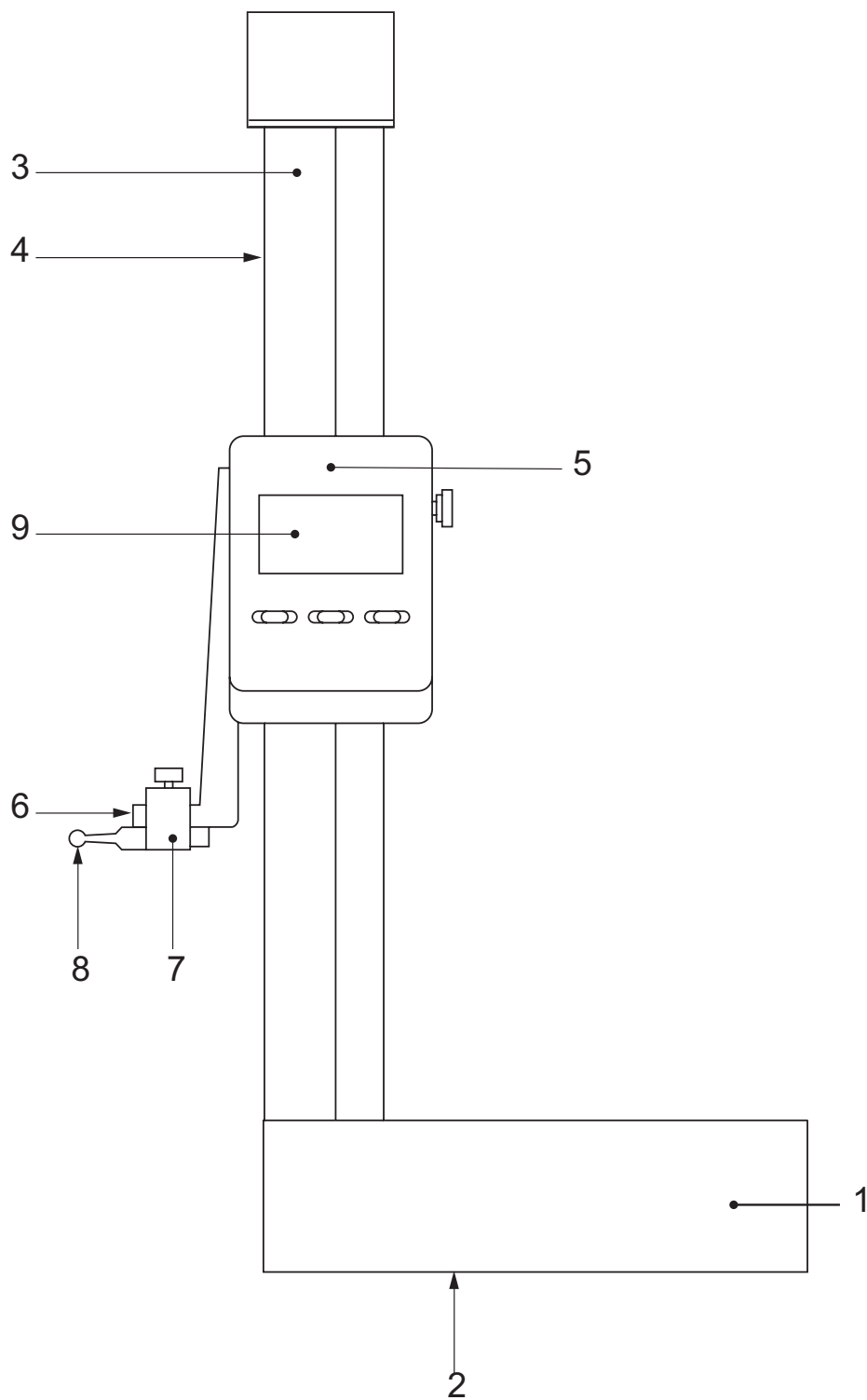
The general terms related to the structure of the height gauge are given and illustrated in Figures 1 and 2. The representations given in Figures 1 and 2 are only examples of height gauge design.



Key

- | | | |
|-----------------------------------|---------------------------------|--------------------|
| 1 instrument base | 6 slider | 11 main scale |
| 2 instrument-base reference plane | 7 probe extension | 12 vernier scale |
| 3 beam | 8 fixing device | 13 locking devices |
| 4 guiding face | 9 measuring and scribing stylus | |
| 5 fine-adjustment device | 10 measuring face | |

Figure 1 — Example and nomenclature of height gauge with vernier scale



Key

- | | |
|-----------------------------------|---|
| 1 instrument base | 6 probe extension |
| 2 instrument base reference plane | 7 fixing device |
| 3 beam | 8 stylus tip (the measuring face in this example) |
| 4 guiding face | 9 digital display |
| 5 slider | |

Figure 2 — Example and nomenclature of height gauge with digital indication on the slider

4.2 Main dimensions

As a minimal requirement, the manufacturer shall specify the main dimensions as shown in Figure 3 and Table 1.

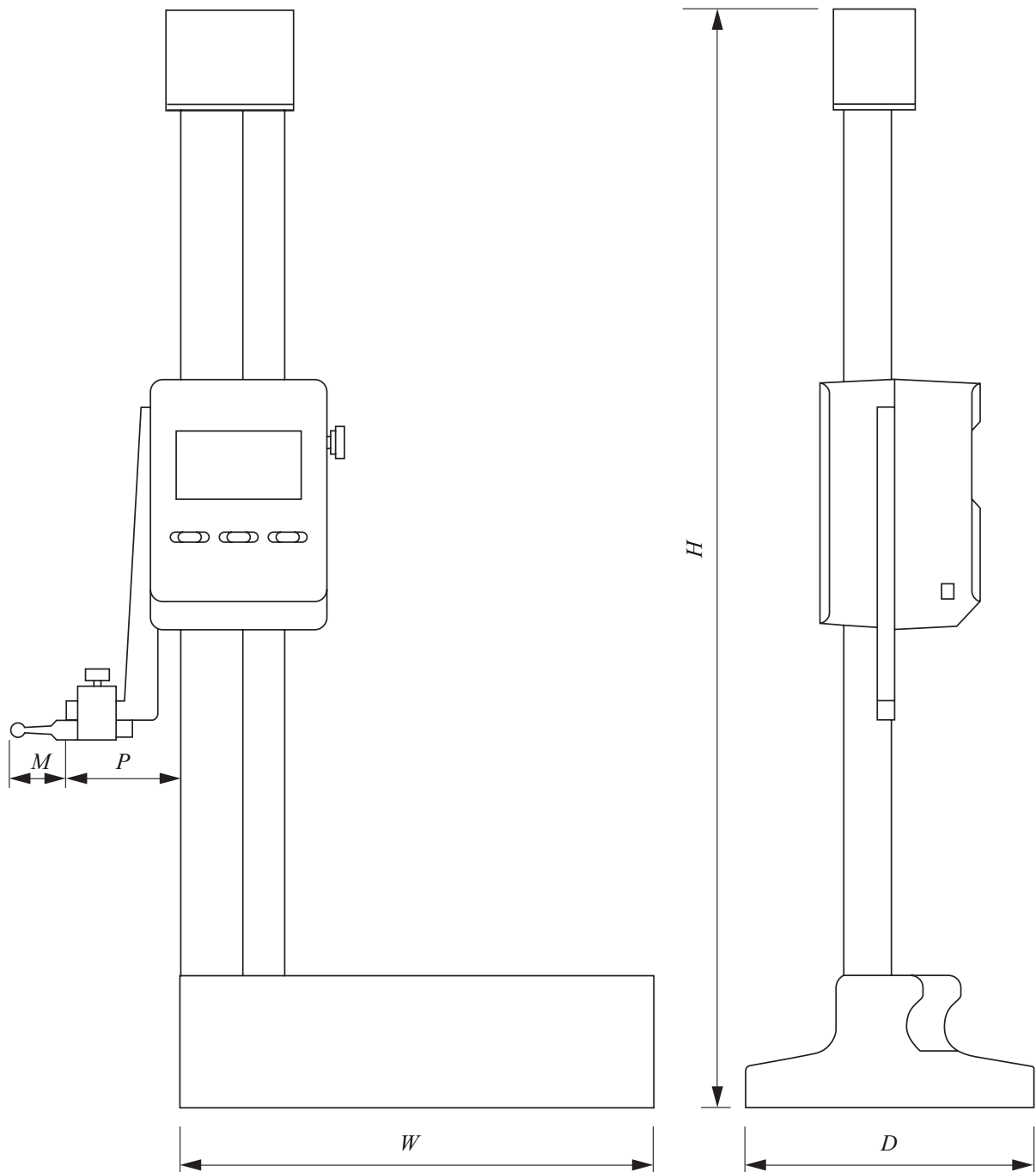


Figure 3 — Main dimensions of height gauge

Table 1 — Main dimensions and design characteristics

Characteristics			
Main dimensions	Width of instrument base	W	mm
	Depth of instrument base	D	
	Overall height	H	
	Measuring range	L	
	Probe extension offset	P	
	Minimum stylus length	M_{min}	
	Maximum stylus length	M_{max}	
Air bearing system	Yes/No	if Yes: air pressure	Pa
		consumption	l/min
Fixing devices	Yes/No		
Presence of fine adjustment	Yes/No		
Protection	Water or dust		IP code
	Yes/No		

4.3 Types of indicating devices

4.3.1 General

Several types of indicating devices are possible:

- analogue indicating devices with a vernier scale or circular scale (see Figures 4 and 9);
- digital indicating devices with digital display (see Figure 10).

NOTE Combinations of these types of indicating devices are possible.

On instruments with analogue indicating devices, the scale interval and its unit shall be labelled.

On instruments with digital indicating devices, the unit of the indication shall be labelled.

4.3.2 Analogue indicating devices with a vernier scale

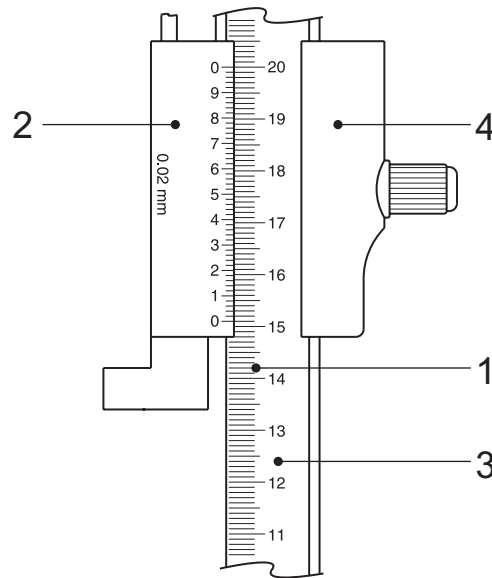
4.3.2.1 General

The scale interval of the main scale on the beam of an instrument with a vernier scale shall be specified in millimetres.

The main scale shall be longer, by at least one vernier scale length, than the measuring range of the instrument.

In the case of instruments with circular scales, the scale interval on the beam may be greater than 1 mm.

4.3.2.2 Main scale and vernier scale



Key

- 1 main scale
- 2 vernier scale
- 3 beam
- 4 slider

Figure 4 — Analogue indication with main and vernier scale

4.3.2.3 Design of vernier scale

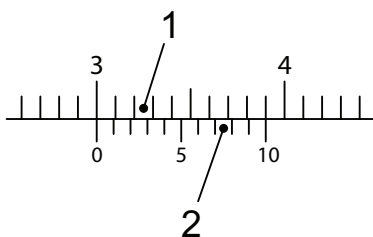
The graduating method of verniers is shown in Table 2.

Table 2 — Graduating method of verniers

Dimensions in millimetres

Main scale interval	Graduating method of vernier	Nominal vernier scale resolution	Explanatory figure
1	Divide 9 mm into 10 equal parts	0,1	Figure 5
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 6

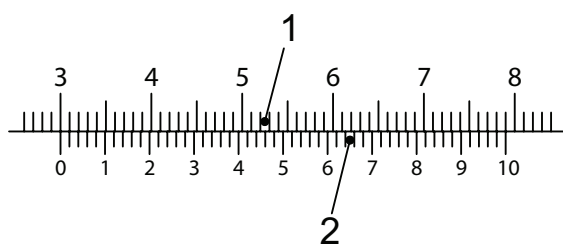
Examples of vernier scales with vernier intervals of 0,1 mm and 0,02 mm are shown in Figures 5 and 6.



Key

- 1 main scale
- 2 vernier scale

Figure 5 — 0,1 vernier scale of length 9 mm



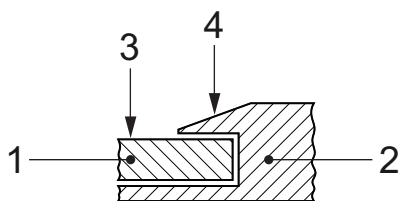
Key

- 1 main scale
- 2 vernier scale

Figure 6 — 0,02 vernier scale of length 49 mm

4.3.2.4 Scale surfaces

Common types of scale surfaces on the slider are shown in Figures 7 and 8.

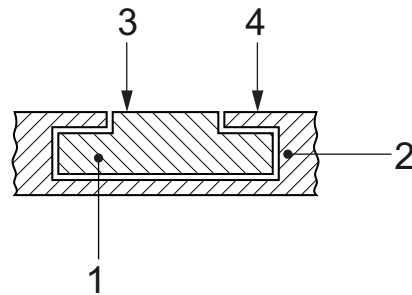


Key

- 1 beam
- 2 slider
- 3 main scale
- 4 vernier scale

Figure 7 — Standard slider with vernier scale

The height difference between the lower edge of the vernier scale surface and the main scale surface should be as small as possible.

**Key**

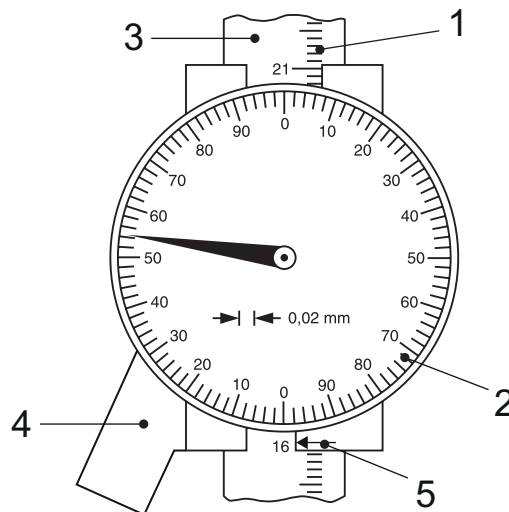
- | | |
|----------|-----------------|
| 1 beam | 3 main scale |
| 2 slider | 4 vernier scale |

Figure 8 — Slider with vernier scale for reading without parallax error

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

4.3.3 Main scale and circular scale

The main scale on the beam and the circular scale on the slider are shown in Figure 9. The circular scale shall be graduated in scale intervals. The scale interval and its unit shall be labelled.

**Key**

- | | |
|------------------|-------------------------|
| 1 main scale | 4 slider |
| 2 circular scale | 5 main scale index line |
| 3 beam | |

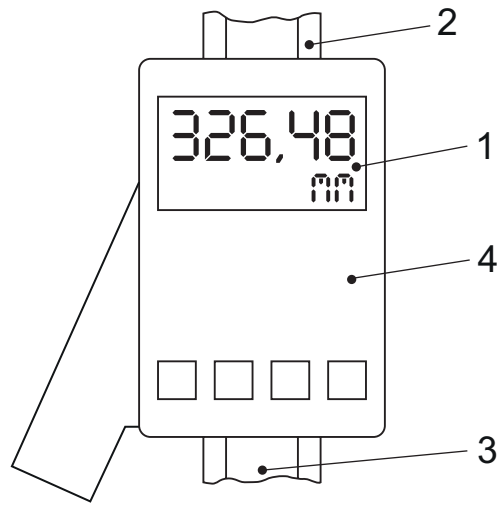
Figure 9 — Scale reading with circular scale

4.3.4 Digital indicating devices

The electronic main scale on the beam and the digital indication on the slider is shown in Figure 10. Instruments with an electronic digital display may also be capable of data transfer. In this case, the manufacturer shall describe the data output protocol (interface) in sufficient detail.

The unit of indication shall be displayed.

The manufacturer should indicate the approximate battery life.



- Key**
- | | |
|-------------------|-------------------------|
| 1 digital display | 3 electronic main scale |
| 2 beam | 4 slider |

Figure 10 — Electronic main scale on the beam and digital indication on the slider

4.4 Protection for field use

Manufacturers should indicate clearly which kind of water and dust protection is provided (IP code, according to IEC 60529).

4.5 Measuring and scribing stylus

The measuring and scribing styli can be interchangeable for various measurements.

The measuring face shall have a wear-resistant and suitable surface finish, and the scribing edge shall be sharp-edged.

4.6 Instrument base

The bottom of the instrument base is the height gauge reference plane.

The instrument base shall be designed in such a manner that safe upright positioning and easy movement of the measuring instrument on the surface plate are guaranteed; it shall also ensure that the measuring instrument cannot slide along across the surface plate.

The instrument base shall be designed to prevent tilting when travelling over the tapped holes or slots on the surface plate.

If there is an air bearing system, the manufacturer shall give the working air pressure and consumption.

4.7 Design characteristics (manufacturer’s specification)

As a minimal requirement, the manufacturer shall specify the design characteristics as shown in Table 1.

5 Metrological characteristics

5.1 General

The manufacturer shall specify the maximum permissible error (MPE) for the height gauge metrological characteristics listed in Table 3; however, not all height gauges require all the MPE values shown. The selection of the MPE values depends on the configuration of the height gauge, as discussed in 5.4.4 and 5.4.5. Unless otherwise specified by the manufacturer, the MPE values shall comply at any position within the measuring range of the height gauge.

According to 7.5.1 of ISO 14978:2006, MPEs shall be given as a continuous function (e.g. straight lines connecting given points); see 7.5.3 of ISO 14978:2006 for the model.

Height gauges with a vernier scale have a fixed zero point. Height gauges with a circular scale shall be able to be set to zero within the range of the circular scale. Height gauges with a digital display shall be able to be set to zero in any position within the measuring range.

5.2 Operating conditions

The MPE values shall apply to any measuring stylus within the allowable lengths stated in Table 1; any additional limitations to the configuration of the measuring stylus shall be stated by the manufacturer.

The manufacturer shall state the flatness of the surface plate used in the specifications of the MPE values.

If not otherwise stated by the manufacturer, the rated operating conditions are at a temperature of 20°C.

The height gauge shall be operated using the procedures given in the manufacturer's operating manual during testing. Specific areas in the manufacturer's manual to be adhered to are, for example:

- a) measuring force;
- b) probe stylus-tip calibration (for bidirectional length measurements);
- c) temperature compensation (if available).

5.3 Effect of slider locking

If the slider is locked, the indication shall fulfil the following:

- instruments with analogue indication: the indication shall not change;
- instruments with digital indication: the indicated value shall not change by more than one digital step.

NOTE The digital display can change by one digital step if the slider is positioned just short of the position where the indication will change.

5.4 Definition of metrological characteristics (limited by MPE)

5.4.1 General

The characteristics on the errors of indication apply to any indication based on the conditions described in 5.1 and 5.2. These characteristics apply independently of the measuring range of the height gauge. The error of indication shall not be greater than the maximum permissible error (MPE).

5.4.2 Length measurement error E (limited by E_{MPE})

The length measurement error, E , is the error of indication when using the height gauge to measure lengths perpendicular to the height-gauge base reference plane and when the contact direction is in a downward direction. The length measurement error applies when either full measuring-face contact (3.2.1) or partial measuring-face contact (3.2.2) is employed. See A.2.2 in Annex A for an example.

5.4.3 Repeatability of length measurement error R (limited by R_{MPE})

The repeatability of length measurement error, R , is the closeness of agreement between the results of successive measurements of the same length measurement carried out at any position on the slider under the same conditions of measurement. See A.2.3 for an example. The manufacturer shall express the manner in which the repeatability is assessed and reported.

5.4.4 Bidirectional length measurement error B (limited by B_{MPE})

The bidirectional length measurement error, B , is the error of indication when using the height gauge to measure lengths perpendicular to the height-gauge base reference plane and when the measured surfaces are in opposing directions. The length measurement error applies when either full measuring-face contact (3.2.1) or partial measuring-face contact (3.2.2) is employed. See A.2.4 for an example.

Not all height gauges are designed for measuring opposing surfaces and therefore B_{MPE} does not apply to all types of height gauges.

5.4.5 Squareness error S (limited by S_{MPE})

The squareness error, S , is the error of indication when using the height gauge to measure perpendicular to the beam while moving the slider parallel to the beam. See A.2.5 for an example.

Not all height gauges are designed for measuring perpendicular to the beam and therefore S_{MPE} does not apply to all types of height gauges.

A height gauge normally requires accessories for measuring squareness. In general, additional measuring equipment, such as a mechanical dial gauge (see ISO 463) and holder, is mounted in place of the measuring stylus. The manufacturer shall state any limitations to the additional measuring equipment for which the S_{MPE} applies.

Table 3 — Metrological characteristics

Characteristic	MPE	
Length measurement error, E		μm
Repeatability of length measurement error, R		
Bidirectional length measurement error, B		
Squareness error, S		
NOTE For the indication of the MPE numerical values, the data sheet given in Annex B can be used		

6 Proving of conformance with specifications

6.1 General

For proving of conformance and non-conformance with specifications, ISO 14253-1 applies. Uncertainty evaluation shall be performed according to ISO/TS 14253-2 and ISO/IEC Guide 98-3 (GUM).

6.2 Measurement standards for the calibration of metrological characteristics

Measurement standards shall be used in accordance with the applicable International Standards.

See Annex C.

7 Marking

The marking shall indicate at least the following data:

- the name or trade mark of the manufacturer/supplier;

- the vernier or circular scale interval (only for analogue indication);
- the unique alphanumeric identification (i.e. serial number).

Any marking shall be easily readable and permanent and shall be placed on the surface of the height gauge at a place that will not impair the metrological quality of the equipment.

Annex A (informative)

Error tests

A.1 Test methods

The test methods should evaluate the performance of the instrument within its measuring range.

The methods described in A.2 do not purport to be the only valid test methods, but it is recommended to use them.

A calibration curve provides the simplest means of evaluating the performance of the height gauge 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 material measures with an appropriate measurement uncertainty, for example, with gauge blocks according to ISO 3650, step blocks or step gauges.

A.2.2 Length measurement error, E (limited by E_{MPE})

The length measurement error can be tested by measuring measurement standards, e.g. gauge blocks, at different positions within the measuring range of the height gauge (see Figure A.1). The measuring direction should always be in the download direction.

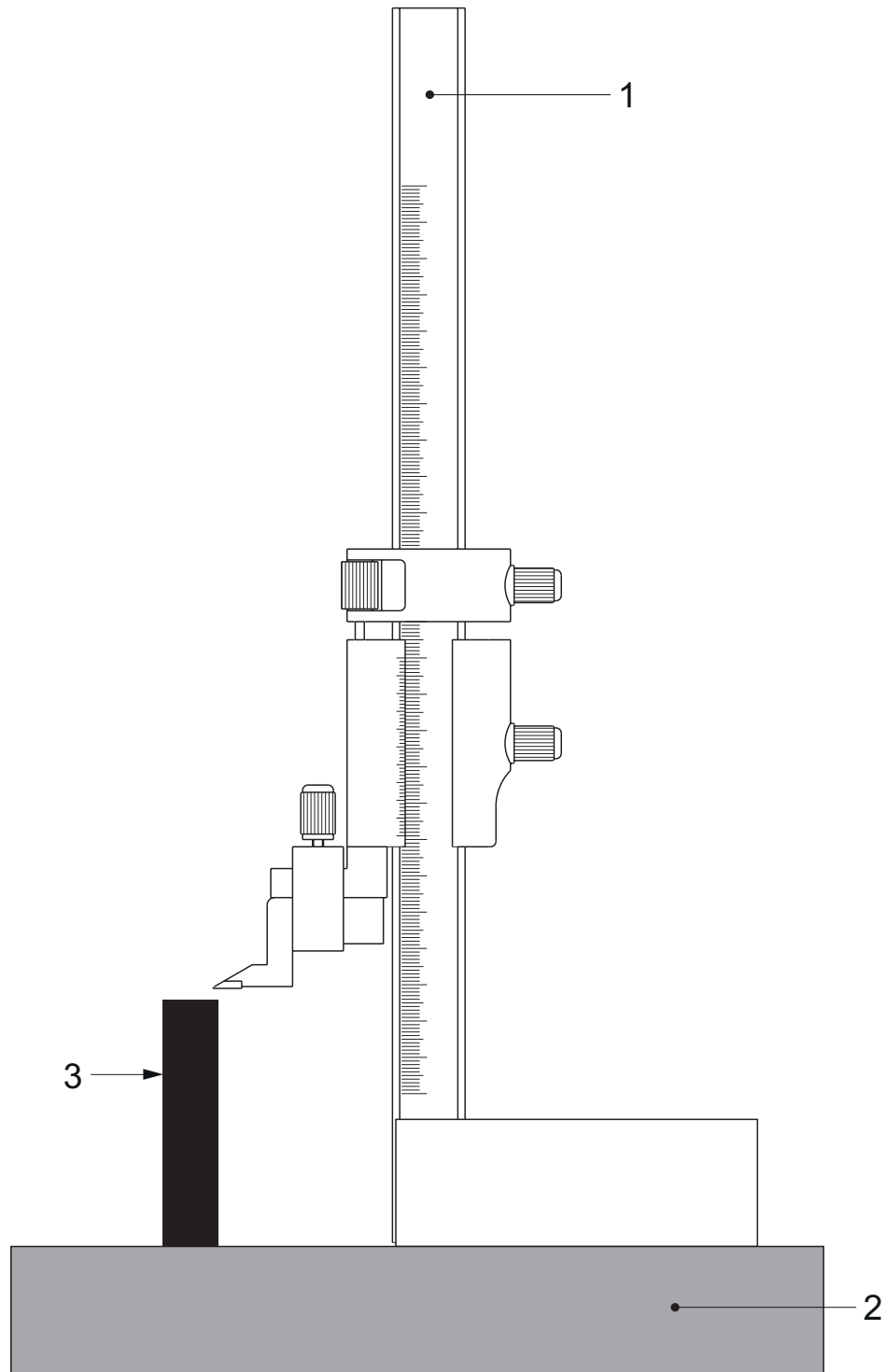
NOTE 1 The length measurement error, E , depends on the usage of the height gauge, e.g. the measuring position within the measuring range and the length and configuration of the measuring stylus.

NOTE 2 Parallelism and form deviation of the measuring face of the stylus, as well as scale errors, are included.

NOTE 3 Form deviations of the surface plate can influence the measurement results.

A.2.3 Repeatability of length measurement error, R (limited by R_{MPE})

The repeatability of the length measurement error may be tested by taking multiple measurements of a measurement standard, e.g. gauge blocks, at any one position within the measuring range of the height gauge (see Figure A.1).



Key

- 1 height gauge
- 2 surface plate
- 3 gauge block

Figure A.1 — Test arrangement for length measurement error

A.2.4 Bidirectional length measurement error B (limited by B_{MPE})

The bidirectional length measurement error may be tested by measuring bidirectional measurement standards, e.g. step gauges, which allow measuring in opposing directions (see Figure A.2).

NOTE 1 The bidirectional length measurement error depends on the usage of the height gauge, e.g. the measuring position within the measuring range and the length and configuration of the measuring stylus.

NOTE 2 Parallelism and form deviation of the measuring face of the stylus, as well as scale errors, are included.

NOTE 3 Form deviations of the surface plate can influence the measurement results.

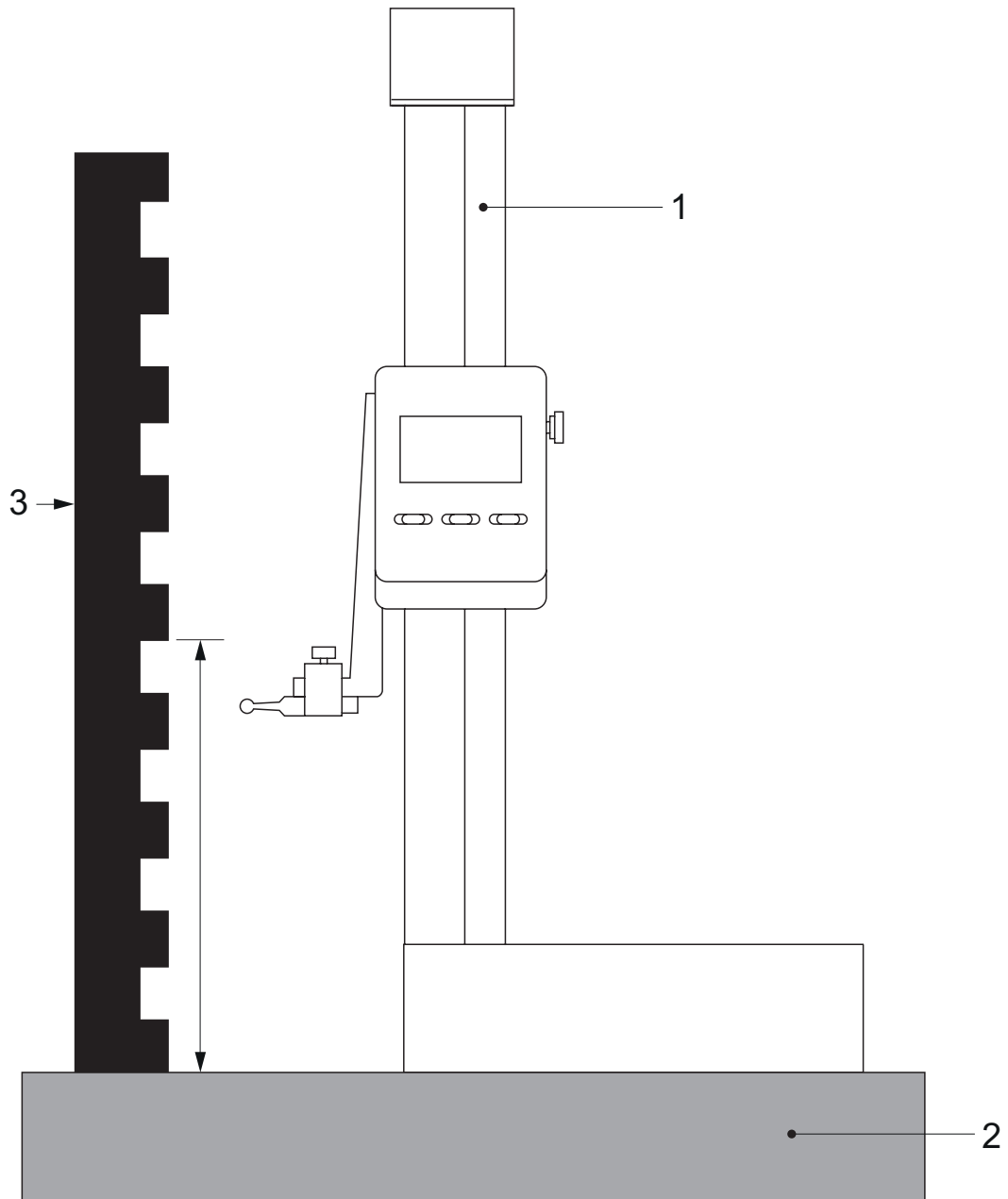
A.2.5 Squareness error S (limited by S_{MPE})

The squareness error, S , may be tested by measuring a measurement standard, e.g. precision square, which allows for errors of indication to be measured perpendicular to the beam of the height gauge and with reference to the surface plate used with the height gauge. The measurement of squareness will usually require the use of additional accessories, such as a mechanical dial gauge (see Figure A.3), which may influence the measurement results.

The square should be aligned by following the method in which the square was calibrated (as much as possible).

NOTE 1 Square reversal techniques could be used that eliminate the need for the calibration of the square. See Reference [5].

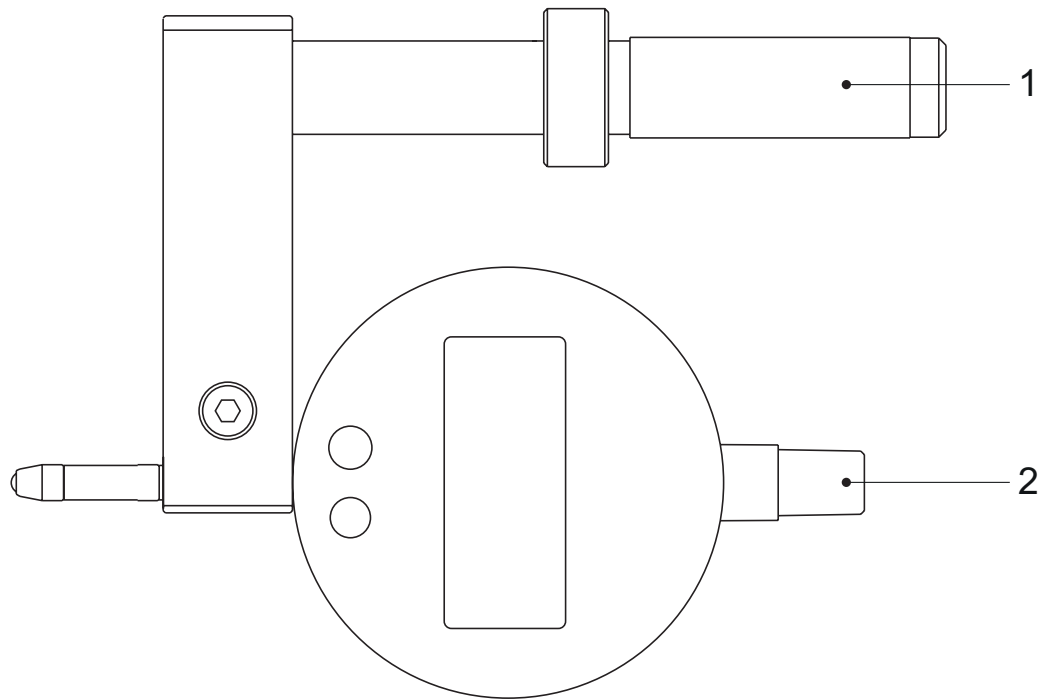
NOTE 2 Form deviations of the surface plate can influence the measurement results.



Key

- 1 height gauge
- 2 surface plate
- 3 step gauge

Figure A.2 — Test arrangement for bidirectional length measurement error using a step gauge



Key

- 1 height gauge probe extension
- 2 accessory gauge

Figure A.3 — Example of accessory gauge used for the measurement of the squareness error

Annex B
(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 requirements (e.g. type of indicating devices, measuring scribing stylus, 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 13225

Design characteristics

Width of instrument base, W:	..... mm	Overall height, H:	..... mm
Depth of instrument base, D:	..... mm	Measuring range, L:	..... mm
Probe extension offset, P:	..... mm	Presence of fine adjustment (yes/no):	.....
Minimum stylus length, M_{min}:	..... mm	Fixing devices (yes/no):	.....
Maximum stylus length, M_{max}:	..... mm	Water and dust protection:	.....
Scale interval/Digital step:	..... mm	Air bearing system (yes/no):	.....

Metrological characteristics

Length measurement error, E_{MPE} : mm

Repeatability of length measurement error, R_{MPE} : mm

Bidirectional length measurement error, B_{MPE} : mm

Squareness error, S_{MPE} : mm

Operating Conditions

Flatness of surface plate: μ m

Measuring probe/stylus/scriber type:

Accessories for squareness measurement:

Organization:

Department: Person responsible:

Date: Signature:

Annex C (informative)

Calibration of metrological characteristics

The methods should evaluate the performance of the instrument within its measuring range.

The global calibration of each scale point or each digital step over the measuring range will necessitate a large number of readings to be taken. When it is considered that the intended use of the instrument 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, the digital step and the measuring range used. By these values, calibration curves with a fixed zero can be recorded (see Figure 5 in ISO 14978:2006).

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.

The manufacturer should indicate the thermal coefficient of linear expansion of the measuring instrument so that the user can convert the measured values to the standard reference temperature of 20 °C (see ISO 1).

NOTE The temperature coefficient of the measuring instrument mainly results from the coefficient of linear expansion of the beam, as well as the material measure, e.g. scale or rack.

Annex D (informative)

Relation to the GPS matrix model

D.1 General

For full details about 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.

D.2 Information about the International Standard and its use

This International Standard provides the most important design and metrological characteristics of height gauges:

- for linear dimensional measurements;
- with analogue indication: vernier scale or circular scale (dial);
- with digital indication.

D.3 Position in the GPS matrix model

This International Standard 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, as graphically illustrated in Figure D.1.

Fundamental GPS standards	Global GPS standards						
	General GPS standards						
	Chain link number	1	2	3	4	5	6
	Size					X	
	Distance					X	
	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							
Areal surface textures							

Figure D.1 — Position in the GPS-matrix model

D.4 Related International Standards

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

Bibliography

- [1] ISO 463, *Geometrical Product Specifications (GPS) — Dimensional measuring equipment — Design and metrological characteristics of mechanical dial gauges*
- [2] ISO 3650, *Geometrical Product Specifications (GPS) — Length standards — Gauge blocks*
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