INTERNATIONAL STANDARD

ISO 1938-1

First edition
2015-11-01

Geometrical product specifications (GPS) — Dimensional measuring equipment —

Part 1:
Plain limit gauges of linear size

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

Partie 1: Calibres lisses à limite de taille linéaire

Reference number
ISO 1938-1:2015(E)

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Contents

Page

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

The committee responsible for this document is ISO/TC 213, *Geometrical product specifications and verification*.

This first edition cancels and replaces ISO/R 1938:1971, which has been technically revised.

ISO 1938 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Dimensional measuring equipment*:

— *Part 1: Plain limit gauges of linear size*

— *Part 2: Reference disk gauges*

This part of ISO 1938 does not include requirements for setting plug gauges and setting ring gauges, which were dealt with in ISO/R 1938:1971, 3.9.4.

This part of ISO 1938 covers the concepts and principles developed in ISO 14978.

Introduction

This part of ISO 1938 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain links E, F and G of the size chain of standards in the general GPS matrix. For more detailed information of the relation of this part of ISO 1938 to other standards and the GPS matrix model, 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.

The terms and concepts used in this first edition of ISO 1938-1 (compared to the former edition ISO/R 1938:1971) have been changed according to needs and terminology in the other GPS standards.

This part of ISO 1938 deals with verification, using plain limit gauges, of linear sizes for features of size when the dimensional specifications are required (see ISO 14405-1), for rigid workpieces.

NOTE Tables 4 and 5 use the modifiers given in ISO 14405-1 and ISO 1101.

Geometrical product specifications (GPS) — Dimensional measuring equipment —

Part 1:
Plain limit gauges of linear size

1 Scope

This part of ISO 1938 specifies the most important metrological and design characteristics of plain limit gauges of linear size.

This part of ISO 1938 defines the different types of plain limit gauges used to verify linear dimensional specifications associated with linear size.

This part of ISO 1938 also defines the design characteristics and the metrological characteristics for these limit gauges as well as the new or wear limits state Maximum Permissible Limits (MPLs) for the new state or wear limits state for these metrological characteristics.

In addition, this part of ISO 1938 describes the use of limit gauges. It covers linear sizes up to 500 mm.

2 Normative references

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

ISO 286-1:2010, *Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 1: Basis of tolerances, deviations and fits*

ISO 1101:2012, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 14405-1:2010, *Geometrical product specifications (GPS) — Dimensional tolerancing — Part 1: Linear sizes*

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

ISO 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 17450-1:2011, *Geometrical product specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

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

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 purpose of this document, the terms and definitions given in ISO 286-1, ISO 14405-1, ISO 17450-2, ISO/IEC Guide 98-3 and ISO/IEC Guide 99 and the following definitions apply.

3.1 Limits

3.1.1
maximum material limit of size
MMLS
limit of size corresponding to the maximum material condition of feature of size

Note 1 to entry: MMLS includes the numerical value for the size and the specified association criteria.

Note 2 to entry: A number of different association criteria for size are given in ISO 14660-2 and ISO 14405-1.

3.1.2
least material limit of size
LMLS
limit of size corresponding to the least material condition of feature of size

Note 1 to entry: LMLS includes the numerical value for the size and the specified association criteria.

Note 2 to entry: A number of different association criteria for size are given in ISO 14660-2 and ISO 14405-1.

3.1.3
upper limit of size
ULS
largest permissible size of a feature of size

Note 1 to entry: ULS is a numerical value.

[SOURCE: ISO 286-1:2010, 3.2.3.1]

3.1.4
lower limit of size
LLS
smallest permissible size of a feature of size

Note 1 to entry: LLS is a numerical value.

[SOURCE: ISO 286-1:2010, 3.2.3.2]

3.1.5
upper specification limit
USL
<of the gauge> limit of a specification for a metrological characteristic of a gauge having the largest value

3.1.6
lower specification limit
LSL
<of the gauge> limit of a specification for a metrological characteristic of a gauge having the smallest value

3.2 Gauge types

3.2.1
limit gauge
gauge designed and intended to verify only if workpiece characteristics are inside or outside the tolerance at one of its tolerance limits

Note 1 to entry: When a limit gauge is designed to verify an internal feature of size (a hole for example), then it can be called internal limit gauge.

Note 2 to entry: When a limit gauge is designed to verify an external feature of size (a shaft for example), then it can be called external limit gauge.

Note 3 to entry: General application of limit gauge is given in Annex A.

Note 4 to entry: A limit gauge may be physical or virtual.

3.2.2
plain limit gauge
physical limit gauge with only one or two gauge elements, each one simulating a perfect feature of size, whose size is derived from upper or lower specification limits of the size of a feature of size

Note 1 to entry: When a plain limit gauge consists of only one element, it is qualified as simple (simple plain limit gauge: GO plain limit gauge or NO GO plain limit gauge).

Note 2 to entry: When a plain limit gauge consists of two elements, it is qualified as double (double plain limit gauge: GO and NO GO).

3.2.3
full form cylindrical plug gauge
gauge type A
plain limit gauge designed to simulate a cylinder as a contacting feature with an internal cylinder

Note 1 to entry: See Table 1.

Note 2 to entry: The GO gauge type A simulates a dimensional specification defining the maximum material limit of size with the envelope requirement when the gauge length is greater or at least equal to the length of the feature of size of the workpiece.

3.2.4
segmental cylindrical bar gauge
gauge type B
plain limit gauge designed to simulate two opposite angular portions of a cylinder as a contacting feature with an internal cylinder

Note 1 to entry: See Table 1.

3.2.5
segmental cylindrical bar gauge with reduced gauging surfaces
gauge type C
segmental cylindrical bar gauge designed to simulate two reduced opposite angular portions of a cylinder as a contacting surface with an internal cylinder

Note 1 to entry: See Table 1.

3.2.6
full form spherical plug gauge
gauge type D
plain limit gauge designed to simulate a circle as a contacting feature with an internal cylinder

Note 1 to entry: See Table 1.

Note 2 to entry: The shape of this gauge type is not spherical, but a torus - per tradition the name is “spherical plug gauge”.

3.2.7
segmental spherical plug gauge
gauge type E
plain limit gauge designed to simulate two opposite angular portions of a circle as a contacting feature with an internal cylinder

Note 1 to entry: See Table 1.

Note 2 to entry: The shape of this gauge type is not spherical but a torus - per tradition the name is “segmental spherical plug gauge”.

3.2.8
bar gauge
gauge type F
full form bar gauge
plain limit gauge designed to simulate two opposite planes as a contacting feature with an internal feature of size consisting of two opposite planes

Note 1 to entry: See Table 1.

3.2.9
rod gauge with spherical ends
gauge type G
plain limit gauge designed to simulate two opposite points as a contacting feature with an internal feature of size consisting of two opposite planes or of a cylinder

Note 1 to entry: See Table 1.

Note 2 to entry: The active part of a rod gauge with spherical ends consists only of two points: the two points at the largest distance between the two spheres.

Table 1 — Types of limit gauge for internal feature of size

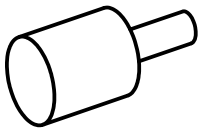
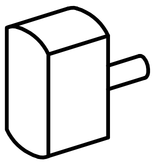
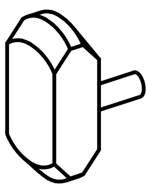
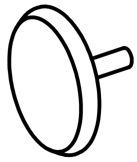
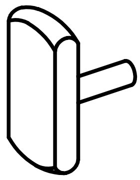
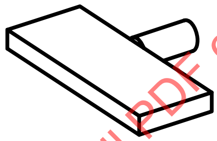
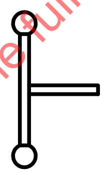
Limit gauge	Type	Illustration	Nominal contacting feature with feature of size of “type Cylinder”	Nominal contacting feature with feature of size of type “two opposite parallel planes”
Full form cylindrical plug gauge	Gauge type A		Cylinder	Two opposite parallel straight lines
Segmental cylindrical bar gauge	Gauge type B		Two opposite angular portions of cylinder	Two opposite parallel straight lines
Segmental cylindrical bar gauge with reduced gauging surfaces	Gauge type C		Two opposite angular reduced portions of cylinder	Two opposite parallel line segments

Table 1 *(continued)*

Limit gauge	Type	Illustration	Nominal contacting feature with feature of size of "type Cylinder"	Nominal contacting feature with feature of size of type "two opposite parallel planes"
Full form spherical plug gauge	Gauge type D		Circle	Two points
Segmental spherical plug gauge	Gauge type E		Two opposite angular portions of circle	Two points
Bar gauge	Gauge type F		Not applicable	Two opposite parallel planes
Rod gauge with spherical ends	Gauge type G		Two points	Two points

3.2.10
full form cylindrical ring gauge
gauge type H
plain limit gauge designed to simulate a cylinder as contacting feature with an external cylinder

Note 1 to entry: See Table 2.

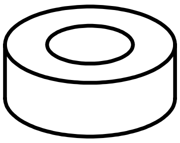
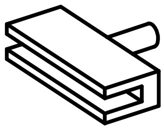
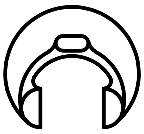
3.2.11
full form notch gauge
gauge type J
plain limit gauge designed to simulate straight lines or flat surfaces on two opposite parallel planes as contacting features with an external feature of size consisting of a cylinder or two opposite planes

Note 1 to entry: See Table 2.

3.2.12
gap gauge
gauge type K
plain limit gauge designed to simulate portions (straight lines or flat surfaces) on two opposite planes as contacting feature with an external feature of size consisting of a cylinder or two opposite planes

Note 1 to entry: See Table 2.

Table 2 — Types of limit gauge for external feature of size

Limit gauge	Type	Illustration	Nominal contacting feature with feature of size of type:	
			"cylinder"	"two opposite parallel planes"
Full form cylindrical ring gauge	Gauge type H		Cylinder	Not applicable
Full form notch gauge	Gauge type J		Two opposite parallel straight lines	Two opposite parallel planes
Gap gauge	Gauge type K		Two opposite parallel straight line segments	Two opposite parallel portions of planes

3.3 Characteristics and function of gauges

3.3.1
non-adjustable gauge
gauge with an inherent, stable and not changeable nominal metrological characteristic

Note 1 to entry: The metrological characteristics of a non-adjustable gauge may change with e.g. temperature and wear.

EXAMPLE A full form cylindrical plug gauge and a full form cylindrical ring gauge are non-adjustable gauges.

3.3.2
adjustable gauge
gauge designed in a way that the inherent nominal metrological characteristic can be intentionally changed by the user

Note 1 to entry: The metrological characteristics of an adjustable gauge may also change with e.g. temperature and wear.

EXAMPLE A variable gap gauge and a variable rod gauge with spherical ends are adjustable gauges.

3.3.3
GO gauge
gauge designed to verify the size of the workpiece relative to maximum material size according to dimensional specification

Note 1 to entry: Usually relative to the maximum material limit of size (MMLS) of the dimensional specification, the GO gauge passing over the actual feature of size of the workpiece, defines an acceptance and the GO gauge, not passing over the actual feature of size of the workpiece defines a non-acceptance.

3.3.4
NO GO gauge
gauge designed to verify the size of the workpiece relative to least material size according to dimensional specification

Note 1 to entry: Usually relative to the least material limit of size (LMLS) of the dimensional specification, the NO GO gauge not passing over the actual feature of size of the workpiece defines an acceptance and the NO GO gauge passing over the actual feature of size of the workpiece defines a non-acceptance.

3.3.5
length of gauge element
active length of a gauge in the direction perpendicular to a cross section of the gauged feature of size

Note 1 to entry: For a cylindrical gauge element, it is the length of the cylinder (see Table 4). For a gauge element of type "two parallel opposite surfaces", it is the length of the bar or notch (see Table 4). For a gap gauge, it is the width of the anvils (see Table 4).

3.3.6
height of gauge element
active height of a gauge in the direction parallel to a cross section of the gauged feature of size

Note 1 to entry: For a gauge element of type two parallel opposite surfaces, it is the height of the bar or notch (see Table 4). For a gap gauge, it is the height of the anvils (see Table 4).

3.3.7
new state specification
<of a limit gauge> specification for metrological characteristics of a new gauge to be used by a manufacturer or supplier

3.3.8
wear limits state specification
<of a limit gauge> specification for metrological characteristics of a used gauge

Note 1 to entry: The user may use standardized wear limits state specifications, e.g. as given in this part of ISO 1938.

Note 2 to entry: The wear limits state specifications consider the gauge as used, and can include wear limits.

3.3.9
new state permissible limits of a metrological characteristic
permissible limits of a metrological characteristic in a new state specification

3.3.10
wear limits state permissible limits of a metrological characteristic
permissible limits of a metrological characteristic in a wear limits state specification

4 Abbreviated terms and symbols

For the purpose of this document, the abbreviated terms and symbols given in Table 3 apply.

Table 3 — Abbreviated terms and symbols

		Description
Abbreviated term		
	B	width of segmental gauge element
	F	tolerance value of form specification on limit gauge
	GO	go gauge
	H	interval tolerance on the size characteristic, S, for a limit gauge in the new state
	LT	length of gauge element
	HG	height of gauge element
	USL	upper specification limit (of a gauge)
	LG	length of gauge element
	LSL	lower specification limit (of a gauge)
	LMLS	least material limit of size
	M	new state gauge
	MMLS	maximum material limit of size
	MPL	maximum permissible limits of a metrological characteristic
	NO GO	no go gauge
	S	size
	SR	spherical radius of the gauge
	T	tolerance
	U	wear limits state gauge
	W	workpiece
Symbol		
	y	amount outside of workpiece tolerance limit taking into account a margin of wear limit for internal feature of size
	y_1	amount outside of workpiece tolerance limit taking into account a margin of wear limit for external feature of size
	z	distance between centre of tolerance for GO new state gauge and the lower specification limit of an internal feature of size of a workpiece
	z_1	distance between centre of tolerance for GO new state gauge and the upper specification limit of an external feature of size of a workpiece
	α	safety allowance for measurement uncertainty for internal feature of size
	α_1	safety allowance for measurement uncertainty for external feature of size

5 Design characteristics for gauges

The material used for gauges shall be suitably selected with due consideration to its size stability, durability and stiffness.

Gauging elements shall normally be manufactured from a high quality steel suitably selected to provide a high degree of wear resistance after heat treatment. Other wear-resistant materials, e.g. tungsten carbide, may be used provided that their wear qualities are not less than those of the steel specified above.

NOTE The temperature expansion coefficient of the material used is to be considered together with the wear resistance.

Hard plating or other surface treatments in order to improve the wear resistance of the surface may also be applied to gauging surfaces, but the thickness of deposit shall at least be of an amount, that an acceptable gauge always has a fully intact layer of wear resistant material.

The hardness of the gauging surface shall not be less than 670 HV 30 (approximately 58 HRC), irrespective of the type of material.

There may be specific applications where the use of special materials (e.g. aluminium and glass) is required by the nature of the workpiece or the manufacturing environment. In such cases it may not be possible to have the required hardness or wear resistance.

The gauging surface shall be finished by fine grinding or lapping or a process which results in a smooth type of surface. The surface roughness of gauging surface shall be specified and the R_a value shall not exceed 10 % of the new state gauge MPL for size (see Example and Table 6) with a upper limit value of 0,2 µm, and cut-off value of 0,8 mm (see ISO 1302).

EXAMPLE Surface texture specification related to R_a parameter on gauging surface: -0,8 / Ra 0,2

Additional surface texture parameters can be specified.

All sharp edges shall be removed unless functionally required.

The design of grip handle of the plain limit gauge shall take into account ergonomic considerations (e.g. knurling, hexagon shape) and the associated characteristics to the grip handle are also design characteristics.

Design options on some gauges are possible; these are given below.

— *Air slot*: for a GO gauge- full form cylindrical plug gauge: this option is intended to verify a blind hole, to avoid phenomena of compression and suction. This option requires defining the air slot dimensions.

— *Precentering/pilot* (see Figure 1): for a GO gauge or a NO GO gauge - full form cylindrical plug gauge and segmental cylindrical bar gauge; this option is intended to facilitate the introduction of the gauge in the workpiece. This option requires defining the precentering or pilot dimensions.

When a gauge with precentering option is used for a blind hole, an air slot option may be used.

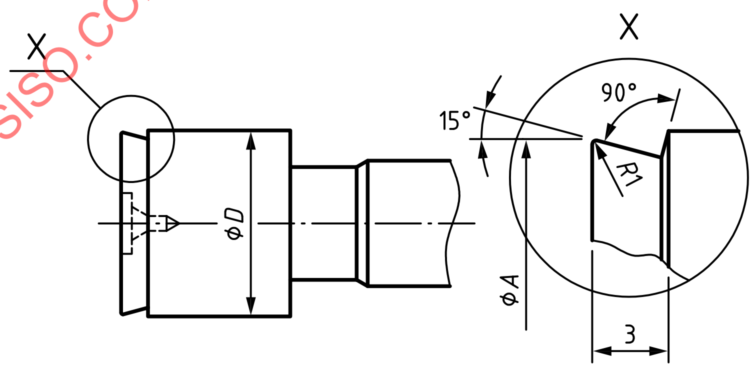


Figure 1 — Illustration of precentering option (example)

Other specific design characteristics, attached to a type of gauge, are described in Tables 4 and 5.

6 Metrological characteristics

6.1 General

A plain limit gauge has one or two gauge elements (GO gauge or NO GO gauge, or GO and NO GO gauge). Metrological characteristics are defined for these gauge elements. These metrological characteristics influence the quality of the evaluation made using the gauge.

The most important metrological characteristics for the gauge elements are the size, S, and form, F. The modifiers defined in ISO 14405-1 and the symbols defined in ISO 1101 can be used to define the metrological characteristics.

The size can be seen metrologically by different ways. For example, on a cylinder, it is possible to evaluate the maximum inscribed diameter, the minimum circumscribed diameter, the minimum local diameter, the maximum local diameter or the least square diameter. Each of them can yield different result of measurement. For this reason, the metrological characteristic includes this information (by adding after the size a modifier as defined in ISO 14405-1).

Depending on the use of the plain gauge and its type, the metrological characteristic impacting the uncertainty of verification can be different, for the same plain gauge.

NOTE When a slot without envelope requirement is checked for its lower limit with a gauge type A, two parallel lines will be checked which do not exactly correspond to the definition for two-point size. The gauge type G is the gauge type that follows the definition for two-point size.

This part of ISO 1938 describes potential metrological characteristics available on plain limit gauge. The final decision to select one or several metrological characteristics is left to the user.

6.2 Metrological characteristic relative to the type of limit gauge (GO gauge or NO GO gauge)

Tables 4 and 5 give potential metrological characteristics associated to a gauge type, but also complementary design characteristics as defined in Clause 5. Depending on the need of the user, a set of these metrological characteristics shall be defined; by default the two point size is required for the size, S, of the gauge limit and the form deviation also.

Table 4 — List of potential design and metrological characteristics for external gauge type

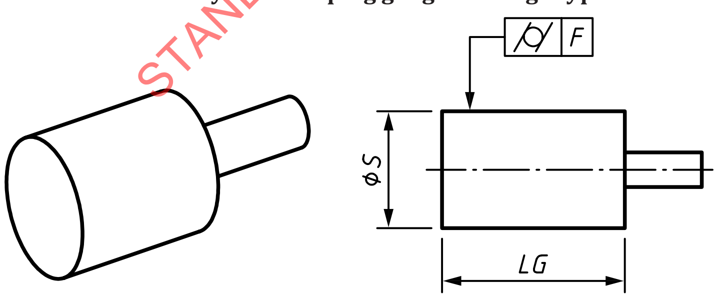
Description	Complementary design characteristics	Metrological characteristics for GO gauge	Metrological characteristics for NO GO gauge
Full form cylindrical plug gauge — Gauge type A 	LG	ϕS (GX) ϕS (GN) ϕS (LP) a ⌭ | F a ○ | F	ϕS (GX) /0 ϕS (GN) /0 ϕS (LP) a ○ | F

Table 4 *(continued)*

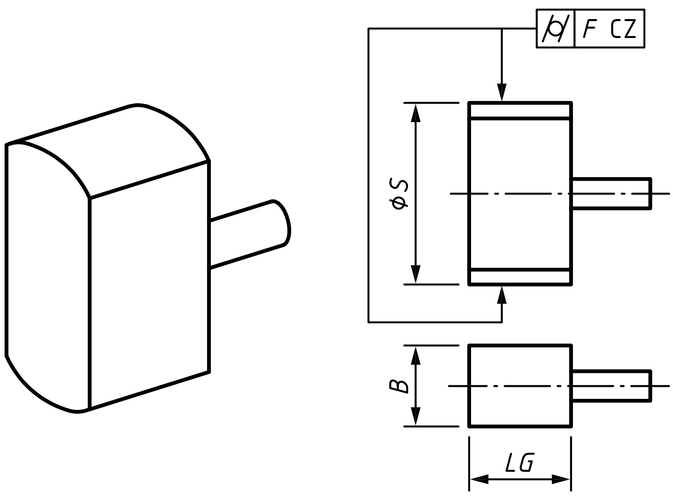
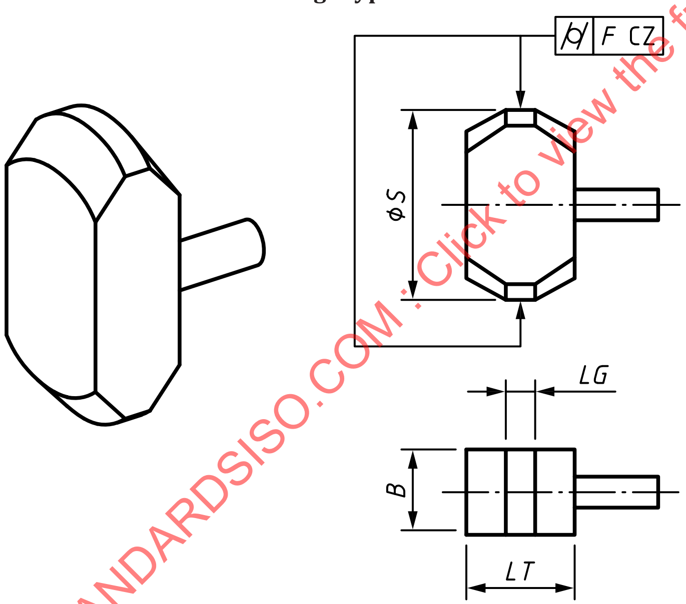
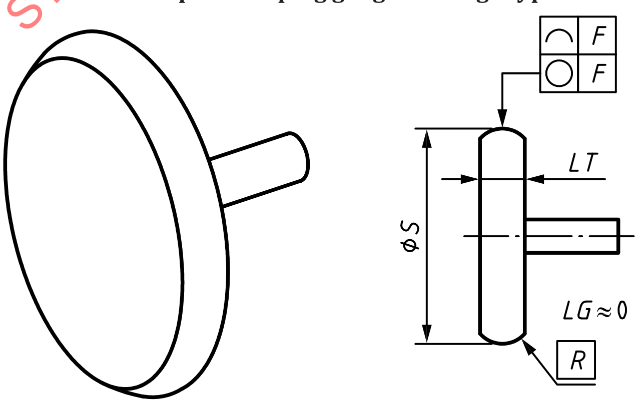
Description	Complementary design characteristics	Metrological characteristics for GO gauge	Metrological characteristics for NO GO gauge
Segmental cylindrical bar gauge — Gauge type B 	LG B	ϕS (GX) CT ϕS (GN) CT ϕS (LP) CT [a] ⌭ F CZ [a] ○ F CZ	ϕS (GX) /0 CT ϕS (GN) /0 CT ϕS (LP) CT [a] ○ F CZ
Segmental cylindrical bar gauge with reduced gauging surfaces — Gauge type C 	LG B LT	ϕS (GX) CT ϕS (GN) CT ϕS (LP) CT [a] ⌭ F CZ [a] ○ F CZ	ϕS (GX) /0 CT ϕS (GN) /0 CT ϕS (LP) CT [a] ○ F CZ
Full form spherical plug gauge — Gauge type D 	R LT	ϕS (GX) /0 ϕS (GN) /0 ϕS (LP) [a] ○ F [a]	ϕS (GX) /0 CT ϕS (GN) /0 CT ϕS (LP) CT [a] ○ F

Table 4 *(continued)*

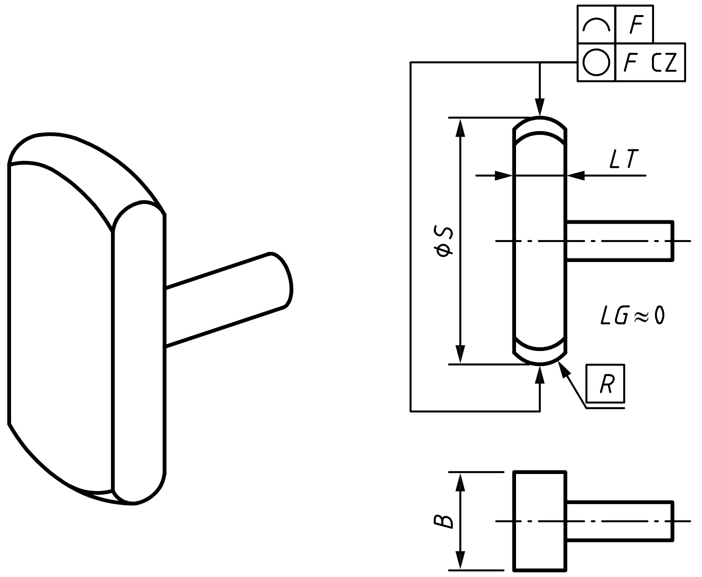
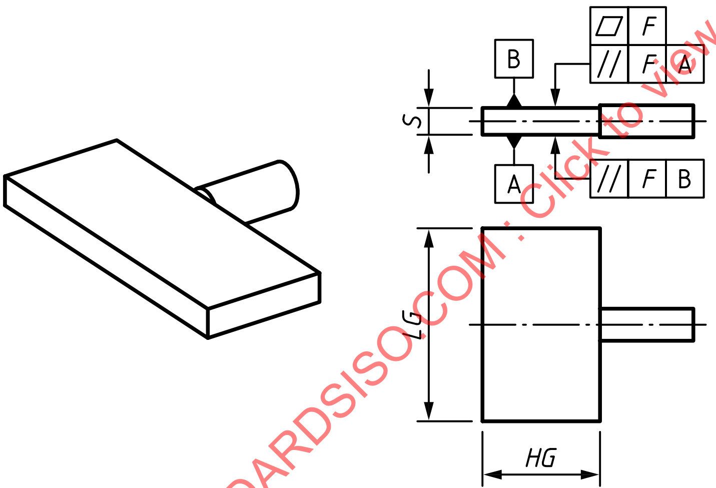
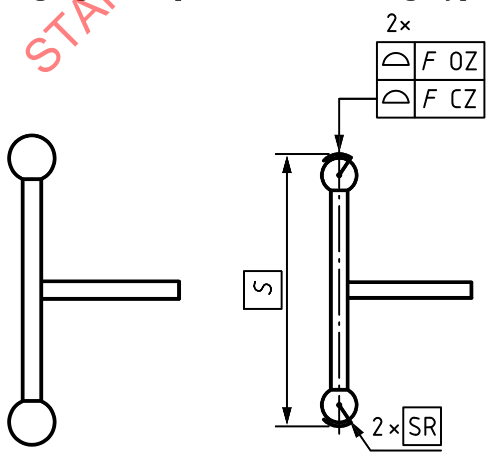
Description	Complementary design characteristics	Metrological characteristics for GO gauge	Metrological characteristics for NO GO gauge
Segmental spherical plug gauge — Gauge type E 	B LT R	ϕS (GX)/0 CT ϕS (GN)/0 CT ϕS (LP) CT a ○ | F CZ	ϕS (GX)/0 CT ϕS (GN)/0 CT ϕS (LP) CT a ○ | F CZ
Bar gauge — Gauge type F 	LG HG	S (GX) S (GN) S (LP) a // | F ▱ | F	S (GX)/0 S (GN)/0 S (LP) a // | F | A // | F | B ▱ | F
Rod gauge with spherical ends — Gauge type G 	SR	ϕS (LP) CT a ⌓ | F OZ	ϕS (LP) CT a ⌓ | F OZ

Table 4 (*continued*)

a default metrological characteristics to be considered	
(GX)	maximum inscribed (see ISO 14405-1)
(GN)	minimum circumscribed (see ISO 14405-1)
(CC)	circumferential (see ISO 14405-1)
(LP)	two point size (see ISO 14405-1)
CT	common tolerance (see ISO 14405-1)

Table 5 — List of potential design and metrological characteristics for internal gauge type

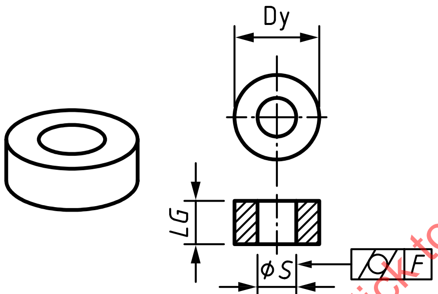
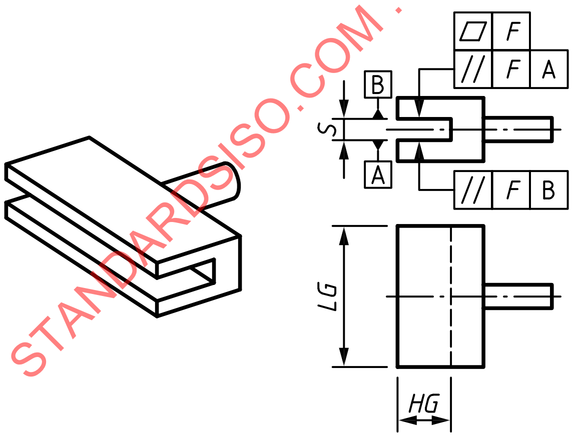
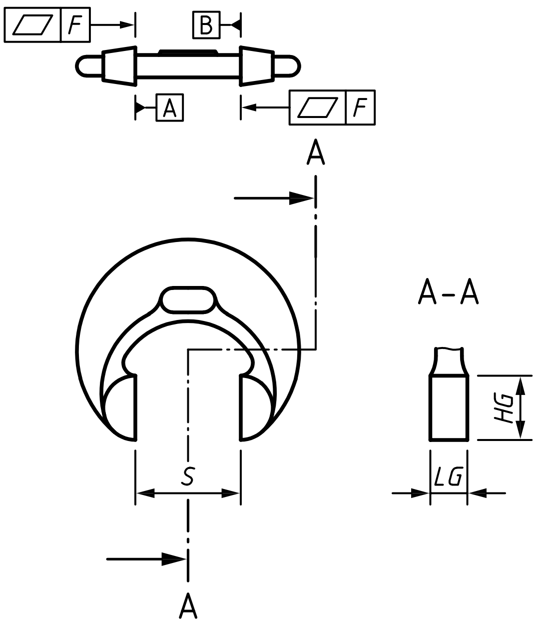
Description	Complementary design characteristics	Metrological characteristics for GO gauge	Metrological characteristics for NO GO gauge
Full form cylindrical ring gauge — Gauge type H  	Dy LG	ϕS (GX) ϕS (GN) ϕS (LP) a |⌭|F| a |○|F|	ϕS (GX)/0 ϕS (GN)/0 ϕS (LP) a |○|F|
Full form notch gauge — Gauge type J  	LG HG	S (GX) S (GN) S (LP)a |//|F|A| |//|F|B| and |▱|F|	S (GX) S (GN) S (LP) |//|F|A| |//|F|B| and |▱|F|
a default metrological characteristics to be considered			
(GX) maximum inscribed (see ISO 14405-1)			
(GN) minimum circumscribed (see ISO 14405-1)			
(LP) two point size (see ISO 14405-1)			

Table 5 *(continued)*

Description	Complementary design characteristics	Metrological characteristics for GO gauge	Metrological characteristics for NO GO gauge
Gap gauge — Gauge type K  Constraint condition: a) normally the dimension HG is vertical compared to the gravity direction b) gap gauges shall only be used for rigid workpieces	LG HG	*S* (GX) *S* (GN) *S* (LP) a and [⏥ | *F*]	*S* (GX) *S* (GN) *S* (LP) a and [⏥ | *F*]

a default metrological characteristics to be considered

(GX) maximum inscribed (see ISO 14405-1)

(GN) minimum circumscribed (see ISO 14405-1)

(LP) two point size (see ISO 14405-1)

7 Maximum permissible limits on metrological characteristics

7.1 General

The maximum permissible limits for a gauge are completely equivalent to the specification limits on a characteristic.

a) The maximum permissible limits on form and orientation characteristics are asymmetrical.

1) The upper limit of MPL on these characteristics is equal to the value of *F* given in Table 6 and depending to the type of the gauge.

2) The lower limit of MPL on these characteristics is equal to 0.

3) The evaluation of these characteristics shall be in accordance with ISO 1101 and shall fulfil MPLs.

EXAMPLE 1 A metrological characteristic of cylindricity with its MPLs is equivalent to the following requirement: [⌭ | *F*]. Its meaning is given in ISO 1101.

b) Specifications for metrological characteristics associated to S to a limit gauge of the same type used as a GO gauge and as a NO GO gauge are different (see 7.2 and 7.3) and applicable by default to the two point size ϕS (LP).

Specifications for new or wear limits state attached to the metrological characteristics associated to S to limit gauges are always different for GO gauges and may be equal for NO GO gauges. The new state specification limits of GO gauges are always positioned inside the workpiece tolerance.

Tables 6 to 11 can be used directly when the tolerance of the dimension of feature of size of workpiece is given as a code according to ISO 286-1:2010. When the size tolerance is not given as an ISO code, the standard tolerance grade shall be defined as the standard tolerance grade corresponding to the first tolerance interval, *T*, given in Tables 7 to 11, lower than the tolerance interval of the workpiece in the same range of nominal sizes.

EXAMPLE 2 For a dimensional specification given on the workpiece, by 20 ± 0,02 (E), the tolerance interval on the workpiece is equal to 40 µm. In Table 8, in the nominal range in which 20 is included, the lower standardized tolerance interval is equal to 33 µm, corresponding to the standard tolerance grade equal to 8, which is to be used to define the metrological characteristic for a plain limit gauge to verify this dimensional specification.

NOTE For GO gauges, the specification limits are positioned by z and z_1 relative to the tolerance limit of the workpiece (see Figures 2 and 3) in order to allow a certain wear and therefore a certain time in use before the size and form is worn outside the specification for the limit gauge.

7.2 Limit gauges for internal features of size

The positions of new state tolerance limits, and wear limits for limit gauges for internal features of size in relation to workpiece tolerance limits are shown in Figure 2.

The NO GO gauge specification is positioned relative to the LMLS of the workpiece tolerance.

The GO gauge specification is positioned relative to the MMLS of the workpiece tolerance.

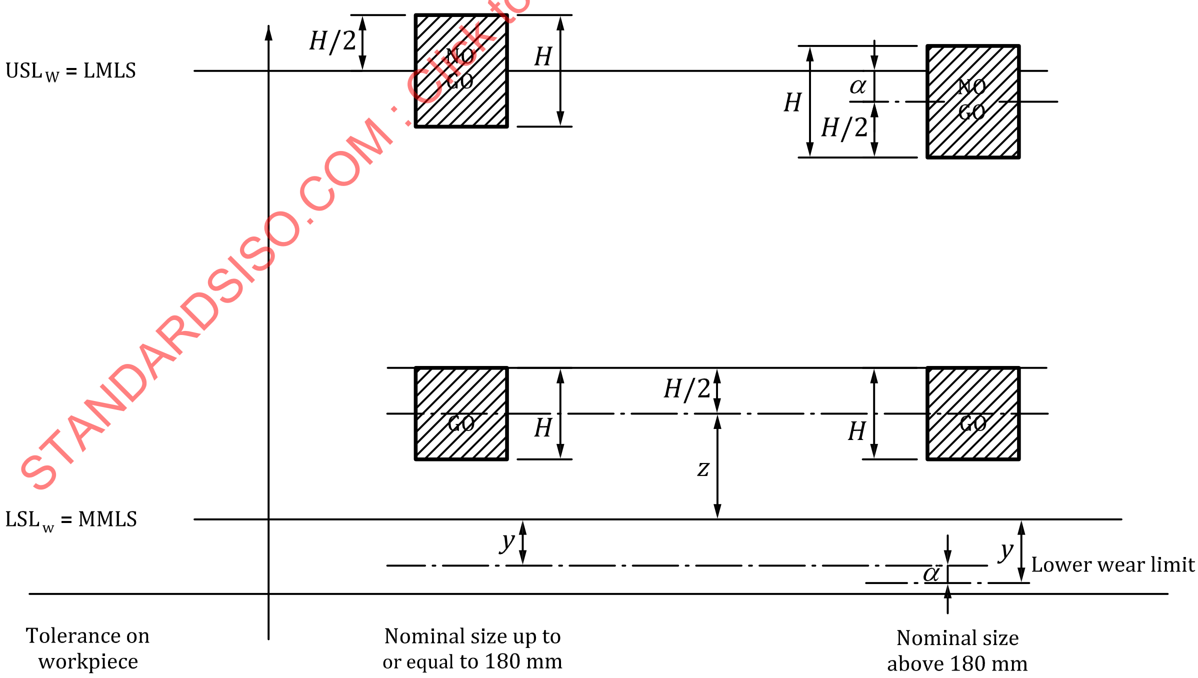


Figure 2 — MPL size position for GO and NO GO gauges for workpieces of internal feature of size

The value for *H* (see Figure 2) is specific for each type of limit gauge, workpiece tolerance grade and workpiece feature size and shall be taken from Table 6.

The values of z, α and y (see Figure 2) is specific for each workpiece tolerance grade and workpiece feature size, and shall be taken from Tables 7 to 11.

When a plug gauge is used as a NO GO limit gauge (for LMLS) of a workpiece feature ($LMLS_W$) the requirement on the size, S, of the gauge element shall be in accordance with the following gauge tolerances for new and wear limits state (see Figure 2):

— for the upper specification limit: $USL_{U,NOGO} = USL_{M,NOGO} = USL_W - \alpha + \frac{H}{2}$

— for the lower specification limit: $LSL_{U,NOGO} = LSL_{M,NOGO} = USL_W - \alpha - \frac{H}{2}$

where α is equal to zero when the nominal value is up to or equal to 180 mm.

When a plug gauge is used as a GO gauge (for MMLS) of a workpiece feature ($MMLS_W$), the requirement on the size, S, of the gauge element shall be in accordance with the following gauge tolerances:

a) for the new state (see Figure 2):

1) for the upper specification limit: $USL_{M,\,GO} = LSL_W + z + \frac{H}{2}$

2) for the lower specification limit: $LSL_{M,\,GO} = LSL_W + z - \frac{H}{2}$

b) for the wear limits state (see Figure 2):

1) for the upper specification limit: $USL_{U,\,GO} = LSL_W + z + \frac{H}{2}$

2) for the lower specification limit: $LSL_{U,\,GO} = LSL_W + \alpha - y$

where

y represents an amount outside of workpiece tolerance limits taking into account a margin of wear limits of GO gauge;

α represents a safety allowance for measurement uncertainty.

7.3 Limit gauges for external features of size

The positions of new state tolerance limits, and wear limits for limit gauges for external features of size in relation to workpiece tolerance limits are shown in Figure 3.

The GO gauge specification is positioned relative to the MMLS of the workpiece tolerance.

The NO GO gauge specification is positioned relative to the LMLS of the workpiece tolerance.

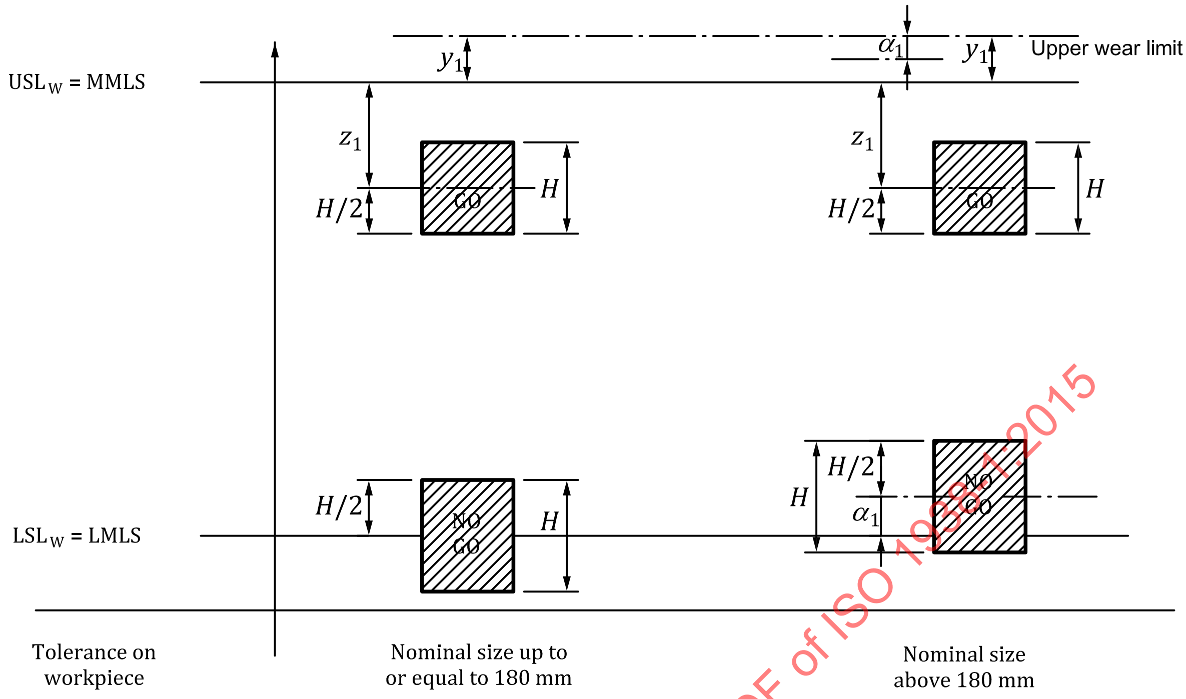


Figure 3 — MPL size position for GO and NO GO gauges for workpieces for an external feature of size

The value for H (see Figure 3) is specific for each type of limit gauge, for workpiece tolerance grade and size and shall be taken from Table 6.

The value of z_1, α_1 and y_1 (see Figure 3) is specific for each workpiece feature size and tolerance grade. Values for z_1, α_1 and y_1 shall be taken from Tables 7 to 11.

When a gauge (type ring) is used as a GO gauge for an external feature of size of a workpiece (MMLS$_W$), the requirement on size, *S*, of the gauge element shall be in accordance with the following gauge tolerances:

a) for the new state (see Figure 3):

1) for the upper specification limit: $\text{USL}_{\text{M, GO}} = \text{USL}_\text{W} - z_1 + \frac{H}{2}$

2) for the lower specification limit: $\text{LSL}_{\text{M, GO}} = \text{USL}_\text{W} - z_1 - \frac{H}{2}$

b) for the wear limits state (see Figure 3):

1) for the upper specification limit: $\text{USL}_{\text{U, GO}} = \text{USL}_\text{W} + y_1 - \alpha_1$

2) for the lower specification limit: $\text{LSL}_{\text{U, GO}} = \text{USL}_\text{W} - z_1 - \frac{H}{2}$

where

y_1 represents an amount outside of workpiece tolerance limits taking into account a margin of wear limits of GO gauge;

α_1 represents a safety zone for compensation of measurement uncertainty.

When a gauge (type ring) is to be used as a NO GO gauge of an external feature of size of a workpiece (LMLS$_W$), the requirement on size, *S*, of the gauge element shall be in accordance with the following gauge tolerances:

— for the upper specification limit (see Figure 3): $\text{USL}_{\text{M,NO GO}} = \text{USL}_{\text{U,NO GO}} = \text{LSL}_\text{W} + \alpha_1 + \frac{H}{2}$

— for the lower specification limit (see Figure 3): $\mathrm{LSL}_{\mathrm{M,NO\ GO}} = \mathrm{LSL}_{\mathrm{U,NO\ GO}} = \mathrm{LSL}_{\mathrm{W}} + \alpha_1 - \frac{H}{2}$

where α_1 is equal to zero when the nominal value is up to or equal to 180 mm.

7.4 Values for calculation of MPL of limit gauges

When the size tolerance of the workpiece is given as a code according to ISO 286-1, use Tables 6 to 11 directly.

When the size tolerance is not given as an ISO code, use the first IT grade in Tables 7 to 11 with a tolerance interval lower than or equal to the tolerance interval in the same nominal size range.

The form limit values are half the values given in column 2 × *F* in Table 6.

When the grade 6 to 8 is associated with the letter N (6N, 7N or 8N), then for the GO gauge the values y, y_1, α and α_1 are equal to zero.

Up to 1 mm, grades IT14 to IT18 are not provided.

Gauges for IT17 and IT18 are of limited usefulness in current gauging practice.

Table 6 — Values of *H* and *F* for calculation of MPL limit gauges in standard tolerance grades according to ISO 286-1

Type of gauge	Workpiece standard tolerance grades									
	IT6		IT7		IT8 to IT10		IT11 and IT12		IT13 to IT18	
	Size	Form and orien-tation	Size	Form and orien-tation	Size	Form and orien-tation	Size	Form and orien-tation	Size	Form and orien-tation
	H	2 × *F*	*H*	2 × *F*	*H*	2 × *F*	*H*	2 × *F*	*H*	2 × *F*
Full form cylindrical plug gauge	IT2	IT1	IT3	IT2	IT3	IT2	IT5	IT4	IT7	IT5
Segmental cylindrical bar gauge										
Segmental cylindrical bar gauge with reduced gauging surfaces										
Full form spherical plug gauge	IT2	IT1	IT2	IT1	IT2	IT1	IT4	IT3	IT6	IT5
Segmental spherical plug gauge										
Bar gauge	IT2	IT1	IT3	IT2	IT3	IT2	IT5	IT4	IT7	IT5
Rod gauge with spherical ends	IT2	IT1	IT2	IT1	IT2	IT1	IT4	IT3	IT6	IT5
Full form cylindrical ring gauge	IT3	IT2	IT3	IT2	IT4	IT3	IT5	IT4	IT7	IT5
Full form notch gauge	IT3	IT2	IT3	IT2	IT4	IT3	IT5	IT4	IT7	IT5
Gap gauge	IT3	IT2	IT3	IT2	IT4	IT3	IT5	IT4	IT7	IT5

Table 7 — Values in micrometres of parameter to define the gauge limits in relation with the workpiece limits — Workpiece standard tolerance grades IT6

Nominal dimension mm		Workpiece standard tolerance grades IT6					
>	≤	T	z	z_1	α, α_1	y	y_1
—	3	6	1	1,5	0	1	1,5
3	6	8	1,5	2	0	1	1,5
6	10	9	1,5	2	0	1	1,5
10	18	11	2	2,5	0	1,5	2
18	30	13	2	3	0	1,5	3
30	50	16	2,5	3,5	0	2	3
50	80	19	2,5	4	0	2	3
80	120	22	3	5	0	3	4
120	180	25	4	6	0	3	4
180	250	29	5	7	2	4	5
250	315	32	6	8	3	5	6
315	400	36	7	10	4	6	6
400	500	40	8	11	5	7	7

Table 8 — Values in micrometres of parameter to define the gauge limits in relation with the workpiece limits — Workpiece standard tolerance grades IT 7 to IT 9

Nominal dimension mm		Workpiece standard tolerance grades											
		IT 7				IT 8				IT 9			
>	≤	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1
—	3	10	1,5	0	1,5	14	2	0	3	25	5	0	0
3	6	12	2	0	1,5	18	3	0	3	30	6	0	0
6	10	15	2	0	1,5	22	3	0	3	36	7	0	0
10	18	18	2,5	0	2	27	4	0	4	43	8	0	0
18	30	21	3	0	3	33	5	0	4	52	9	0	0
30	50	25	3,5	0	3	39	6	0	5	62	11	0	0
50	80	30	4	0	3	46	7	0	5	74	13	0	0
80	120	35	5	0	4	54	8	0	6	87	15	0	0
120	180	40	6	0	4	63	9	0	6	100	18	0	0
180	250	46	7	3	6	72	12	4	7	115	21	4	0
250	315	52	8	4	7	81	14	6	9	130	24	6	0
315	400	57	10	6	8	89	16	7	9	140	28	7	0
400	500	63	11	7	9	97	18	9	11	155	32	9	0

Table 9 — Values in micrometres of parameter to define the gauge limits in relation with the workpiece limits — Workpiece standard tolerance grades IT 10 to IT 12

Nominal dimension mm		Workpiece standard tolerance grades											
		IT10				IT 11				IT 12			
>	≤	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1
—	3	40	5	0	0	60	10	0	0	100	10	0	0
3	6	48	6	0	0	75	12	0	0	120	12	0	0
6	10	58	7	0	0	90	14	0	0	150	14	0	0
10	18	70	8	0	0	110	16	0	0	180	16	0	0
18	30	84	9	0	0	130	19	0	0	210	19	0	0
30	50	100	11	0	0	160	22	0	0	250	22	0	0
50	80	120	13	0	0	190	25	0	0	300	25	0	0
80	120	140	15	0	0	220	28	0	0	350	28	0	0
120	180	160	18	0	0	250	32	0	0	400	32	0	0
180	250	185	24	7	0	290	40	10	0	460	45	15	0
250	315	210	27	9	0	320	45	15	0	520	50	20	0
315	400	230	32	11	0	360	50	15	0	570	65	30	0
400	500	250	37	14	0	400	55	20	0	630	70	35	0

Table 10 — Values in micrometres of parameter to define the gauge limits in relation with the workpiece limits — Workpiece standard tolerance grades IT13 to IT15

Nominal dimension mm		Workpiece standard tolerance grades											
		IT13				IT14				IT15			
>	≤	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1
—	3	140	20	0	0	250	20	0	0	400	40	0	0
3	6	180	24	0	0	300	24	0	0	480	48	0	0
6	10	220	28	0	0	360	28	0	0	580	56	0	0
10	18	270	32	0	0	430	32	0	0	700	64	0	0
18	30	330	36	0	0	520	36	0	0	840	72	0	0
30	50	390	42	0	0	620	42	0	0	1000	80	0	0
50	80	460	48	0	0	740	48	0	0	1200	90	0	0
80	120	540	54	0	0	870	54	0	0	1400	100	0	0
120	180	630	60	0	0	1000	60	0	0	1600	110	0	0
180	250	720	80	25	0	1150	100	45	0	1850	170	70	0
250	315	810	90	35	0	1300	110	55	0	2100	190	90	0
315	400	890	100	45	0	1400	125	70	0	2300	210	110	0
400	500	970	110	55	0	1550	145	90	0	2500	240	140	0

Table 11 — Values in micrometres of parameter to define the gauge limits in relation with the workpiece limits — Workpiece standard tolerance grades IT16 to IT18

Nominal dimension mm		Workpiece standard tolerance grades											
		IT16				IT17				IT18			
>	≤	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1	T	z, z_1	α, α_1	y, y_1
—	3	600	40	0	0	1000	80	0	0	1400	80	0	0
3	6	750	48	0	0	1200	96	0	0	1800	96	0	0
6	10	900	56	0	0	1500	112	0	0	2200	112	0	0
10	18	1100	64	0	0	1800	125	0	0	2700	125	0	0
18	30	1300	72	0	0	2100	140	0	0	3300	140	0	0
30	50	1600	80	0	0	2500	160	0	0	3900	160	0	0
50	80	1900	90	0	0	3000	180	0	0	4600	180	0	0
80	120	2200	100	0	0	3500	200	0	0	5400	200	0	0
120	180	2500	110	0	0	4000	220	0	0	6300	220	0	0
180	250	2900	210	110	0	4600	360	180	0	7200	470	230	0
250	315	3200	240	140	0	5200	400	200	0	8100	520	250	0
315	400	3600	280	180	0	5700	450	230	0	8900	600	280	0
400	500	4000	320	220	0	6300	500	250	0	9700	710	320	0

8 Proving conformance with specification for limit gauges

By default, when proving conformance and non-conformance to the specifications, ISO 14253-1:2013 applies when the conformance/non-conformance assessment uses the analysis of a measurement result associated to its uncertainty, except when a special agreement exists between the customer and the supplier. Uncertainty evaluation shall be performed according to ISO/IEC Guide 98-3, and more specifically according to ISO 14253-2:2011.

9 Verification of dimensional specification of a workpiece with limit gauges

In the case of verification coming from a plain gauge, there is no measurement result, only verification "GO" or "NO GO" coming from use of a GO gauge or NO GO gauge:

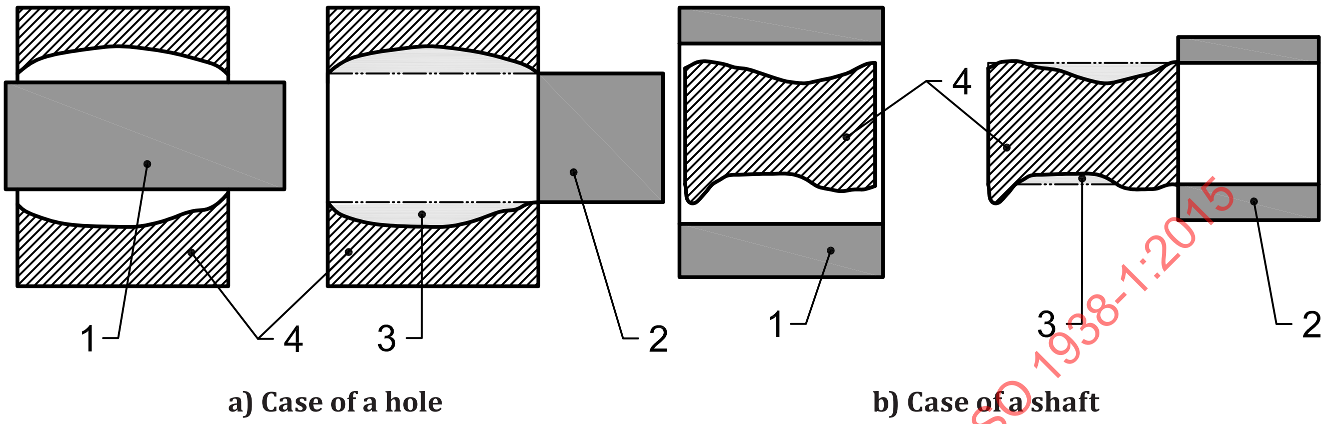
a) the GO gauge shall fit (go) entirely relatively to the concerned surface of the workpiece;

b) the NO GO gauge shall not begin to fit (NO GO) relatively to the concerned surface of the workpiece.

Based on the mathematical analysis of both the workpiece and gauge tolerances limits and having taken into account the uncertainty concept, there is a risk when assessing a workpiece as conforming to specifications when using a GO gauge or NO GO gauge. This is especially true when the tolerances locations of the gauge are taken into account relative to the workpiece tolerances.

— In actual work, this risk for a GO gauge tends to zero when taking into account the location of the GO gauge tolerances relative to the workpiece tolerances. In order to fit a gauge in a workpiece, it is mechanically necessary to have a clearance between the workpiece and the GO gauge. For this reason, if the GO gauge fits into the workpiece, there is a low risk of falsely declaring conformity to the maximum material limit of the dimensional specification of a workpiece, (no contribution of form deviation inside the workpiece, excess of tolerance limits of the GO gauge compared with the workpiece tolerance). When the GO gauge is at the wear limits there is a greater risk of falsely declaring conformity of a workpiece. For this reason, it is important to carefully manage the wear limits.

— For the NO GO gauge, the major risk of using the NO GO gauge depends on the workpiece form deviation (See Figure 4). For this reason, if the NO GO gauge does not fit into the workpiece, there is a risk of falsely declaring conformity to the least material limit of the dimensional specification of a workpiece (form deviation inside of workpiece, excess of tolerance limits of NO GO gauge compared to workpiece's tolerance).



Key

1 GO gauge

2 NO GO gauge

3 Zone form deviation of conformance risk

4 Real workpiece

Figure 4 — Impact of deviation form on proving of conformance of workpiece

Limit gauges described in this part of ISO 1938 are mainly intended for the verification of tolerances on rigid workpieces.

The tolerances for limit gauges given in this part of ISO 1938 are valid at the default condition for temperature in the GPS field (20 °C), see ISO 1.

Limit gauges shall generally be in accordance with the size specification operator specified on the technical product documentation (TPD) to be able to function as a perfect verification operator (see also Annex B, when limit gauges are used as simplified verification operators). The size specification operator shall be indicated on the TPD according to ISO 14405-1.

Especially important for the limit gauge being a perfect verification operator for the indicated specification operator is:

— gauge type shall be correct according to the indicated specification operator, e.g. default specification or specification modifier(s);

— length of gauge element and if relevant also the width of the gauge element shall be in accordance with the specification operator indicated on the technical product documentation (TPD).

During the process of verification of a limit gauge, each metrological characteristic (example: size S) is evaluated, and associated with its uncertainty of measurement. This uncertainty of measurement shall be taken into account for the decision of the conformance of the plain limit gauge.

The size of the gauge is associated with its uncertainty of measurement, *U*. This uncertainty shall be taken into account during the process of verification and for the decision "conformance" or "non-conformance".

EXAMPLE 1 If the evaluated characteristic is a two point size and the specification to verify on the workpiece is also a two point size then the uncertainty to consider is the measurement uncertainty on the two point size.

EXAMPLE 2 If the evaluated characteristic is a two point size and the specification to verify on the workpiece is a global size of type GG distance (see ISO 14405-1) then the measurement uncertainty to consider is the measurement uncertainty on the two point size complemented by two times the default form of the gauge.

10 Marking

Each gauge shall be legibly and permanently marked with the following:

— size tolerance of the workpiece given by:

  — the workpiece tolerance limits, or

  — by ISO code (nominal size value of the workpiece with the symbol designating the tolerance class according to ISO 286-1), or

  — by the nominal size value of the workpiece, with the lower and upper deviation of the workpiece, or with only the suitable deviation (lower or upper) depending of the gauge type (GO or NO GO) and its nature (internal or external): see 7.2 and 7.3,

and

— the type of limit gauge: GO or NO GO, or by colour coding: green for GO gauge (optional) and red for NO GO gauge.

EXAMPLE 1 20 H6 GO or 0 20 H6 +13 GO or 0 20 H6 GO

EXAMPLE 2 12,1 ±0,15 NO GO or −150 12,1 ±0,15 +150 NO GO

EXAMPLE 3 12,25 −0,3 / 0 NO GO

EXAMPLE 4 11,95 / 12,5 NO GO

— the serial number (alphanumerical);

— the manufacturer's name or trademark.

The marking shall not be on gauging surfaces and shall not affect the metrological characteristics of the gauges.

Annex A
(informative)

General principles and application of limit gauging

A.1 General principles

To verify, by gauging, a size specification defined by a bilateral tolerance for a workpiece feature of size according to the indicated specification operator on the technical product documentation, two gauges are used, a GO gauge according to the type of size indicated by the specification operator and a NO GO gauge according to the type of size indicated by the specification operator.

The GO gauge passes into/over the workpiece feature without using excessive force. The gauge passes the total length of the feature.

The NO GO gauge does not pass into/over the workpiece feature without using excessive force.

NOTE When more than one gauge is used for gauging of the same tolerance limit (e.g. by the machine tool and in the quality function at a suppliers plant and a third gauge at the customers plant) disagreement of compliance for the workpiece may occur because of the relatively large tolerances for gauges in relation to the workpiece tolerance. In such cases, the gauge with the size closest to the workpiece tolerance limit is giving the most correct evaluation.

A.2 Application

A.2.1 General

The limit gauging allows the verification of a limit of a specification including dimension, by a physical process without the use of mathematical tools by the user.

In the case of plain limit gauges described in this part of ISO 1938, the limit gauging consists in the verification to a size characteristic of a feature of size.

The limit gauging is not a technique used in a measurement process to give a numerical value of a characteristic. It is a technique used in a checking process to provide only one out of two possible results (Yes/No, GO/NO GO, Accepted/Not accepted, etc.).

There are two types of limit gauging, the limit gauging of the size relative to the maximum material, and the limit gauging of the size relative to the least material.

Inspection by limit gauges is recognized as authoritative for acceptance, and it is agreed that a workpiece size specification is satisfactory if the result of inspection by a gauge is conforming with the requirements of this part of ISO 1938.

To avoid any dispute requiring verification of the gauges of the manufacturer, the following procedure is recommended in the use of gauges of the manufacturer and the purchaser.

A.2.2 Use of new gauge and wear limit gauge by the manufacturer

Generally, the inspection department of the manufacturer that checks the workpieces made in the workshop can use the same types of gauges as those used in the workshop. In order to avoid differences between the results obtained by the workshop and inspection department, it is recommended that the workshop uses new or only slightly worn GO gauges while the inspection department uses GO gauges having sizes nearer the permissible wear limit.

