International Standard

ISO 14405-1

Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 1: Linear sizes

Spécification géométrique des produits (GPS) — Tolérancement dimensionnel —

Partie 1: Tailles linéaires

Third edition
2025-08

Reference number
ISO 14405-1:2025(en)

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Published in Switzerland

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Foreword

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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 document 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).

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

This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and verification*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 14405-1:2016), which has been technically revised.

The main changes are as follows:

— the use of linear size specifications for cones, torus and two opposite circles is now reduced to the cases described in Annexes D, E and F;

— the syntax is changed, and is now defined with several indication areas, and a sequence of specification elements in each area;

— linear size specifications can be stacked upon each other and the rules for stacked specifications are defined;

— the indication *k*×/*n*× is now possible, in order to facilitate stacking with geometrical specifications;

— the graphical rules are modified;

— the specification element “/0” to mean “any restricted portion whose length is equal to zero” has been removed to use the modifier “ACS”;

— when different specification operators applied for the upper and the lower specification limits of size characteristic, the new rule is to indicate two different size specifications;

— the indication of several linear size specifications on the same dimension line or reference line with brackets is removed;

— it is now required to use the “between” symbol to indicate that a linear size specification applies to a fixed restricted portion of a feature of linear size;

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— it is now required to indicate “SCS” with the identifier of the section for a specific cross-section;

— the rank-order size specification is now called statistical size specification.

A list of all parts in the ISO 14405 series can be found on the ISO website.

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

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Introduction

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

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 the specifications made in accordance with this document, unless otherwise indicated.

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

This document deals with linear size specifications on the following features of linear size:

— cylinders;

— spheres;

— two parallel opposite planes.

It also deals with the following cases:

— circles as sections of a cone;

— circles as sections of a torus;

— parallel opposite lines as longitudinal sections of cylindrical tubes.

Different specification elements allow specifying local linear sizes or global linear sizes of different types, and, for example, specifications on several features of linear size, specifications in sections and specifications on portions. The many specification elements allow for specifying a variety of functional needs.

Annex D provides the definition of a size for a circle as section of a cone. Annex E provides the definition of sizes for circles as sections of a torus. Annex F provides the definition of sizes for parallel opposite lines as longitudinal sections of cylindrical tubes in half planes containing a specified axis. Annex H gives an overview of the sequence of specification elements for linear size specifications.

ISO 14405-2 gives the difference between linear size, angular size and dimensions other than linear or angular sizes. ISO 14405-2 relies on this document for the rules about indication.

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Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 1: Linear sizes

IMPORTANT — The figures included in this document are intended to either illustrate the text or to provide examples of the related technical drawing specification, or both. These figures are not fully specified, showing only the relevant general principles. As a consequence, the figures are not a representation of a complete workpiece and are not of a quality that is required for use in industry and, as such, are not suitable for projection for teaching purposes. Figures are simplified 2D representations and show features that are unlikely (e.g. a minimum circumscribed cylinder with three contact points in the same section).

1 Scope

This document specifies requirements for indicating linear sizes.

This document establishes the default specification operator (see ISO 17450-2) and defines a special specification operator for linear sizes.

This document is applicable to the following features of linear size (see ISO 17450-1):

— cylinders;

— spheres;

— two parallel opposite planes.

This document provides a set of tools to express several types of linear size characteristics. It does not present any information on the relationship between a function or a use and a linear size characteristic.

2 Normative references

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

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

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

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

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

ISO 17450-3, *Geometrical product specifications (GPS) — General concepts — Part 3: Toleranced features*

ISO 81714-1, *Design of graphical symbols for use in the technical documentation of products — Part 1: Basic rules*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 286-1, ISO 8015, ISO 17450-1, ISO 17450-2, ISO 17450-3 and the following apply.

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

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

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

3.1
size
dimensional parameter considered variable for a feature of size that can be defined on a nominal feature or on an associated feature

Note 1 to entry: A size is angular (e.g. angle of a cone) or linear (e.g. diameter of a cylinder). This document only applies to *linear sizes* (3.2). See ISO 14405-3 for angular sizes.

Note 2 to entry: Depending on the type of feature of linear size, the terms “diameter”, “width", and “thickness” are synonyms for size.

3.2
linear size
dimension in length units characterizing a feature of size

[SOURCE: ISO 14405-2:2018, 3.2]

3.3
size characteristic
characteristic relative to a *size* (3.1) and defined from an extracted integral feature

Note 1 to entry: A size can be evaluated by more than one size characteristic (e.g. the two-point diameter or the diameter of the associated feature).

3.4
upper specification limit of size characteristic
largest permissible value for a *size characteristic* (3.3)

3.5
lower specification limit of size characteristic
smallest permissible value for a *size characteristic* (3.3)

3.6
local linear size
size characteristic (3.3) having a non-unique result of evaluation either along or around, or both, a feature of *linear size* (3.2)

Note 1 to entry: For a given feature of linear size, an infinity of local linear sizes exists.

Note 2 to entry: In Figure 3, examples of local linear sizes are shown. These examples do not take into account the *statistical size* (3.7.6).

3.6.1
two-point size
<local linear size> distance between two opposite points on an extracted integral feature of *linear size* (3.2)

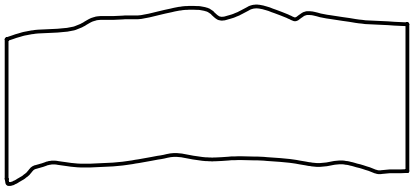
Note 1 to entry: A two-point size on a cylinder can be called a “two-point diameter”.

Note 2 to entry: A two-point size on two parallel opposite planes can be called a “two-point thickness” or a “two-point width”.

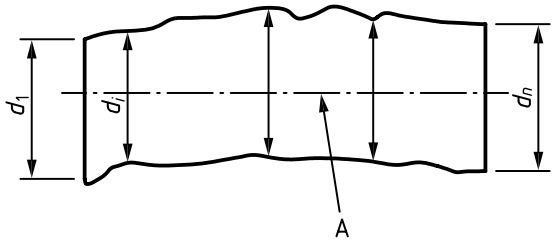
Note 3 to entry: The method establishing a two-point size from any kind of features of linear size is given in ISO 17450–3.

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Note 4 to entry: See Figure 1 for examples of two-point sizes. Figure 1 a) shows an extracted feature under consideration, a cylinder which can be either internal or external.



a) Extracted feature under consideration



b) Two-point sizes

Key

d size

A axis of the least-squares associated cylinder with the extracted integral feature

Figure 1 — Examples of two-point sizes

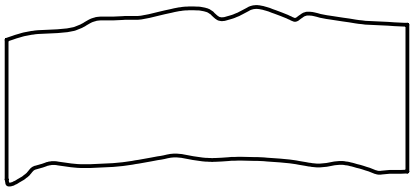
3.6.2
spherical size

<local linear size> diameter of the maximum inscribed sphere

Note 1 to entry: The maximum inscribed sphere is used when defining the spherical size of both internal and external features of *linear size* (3.2).

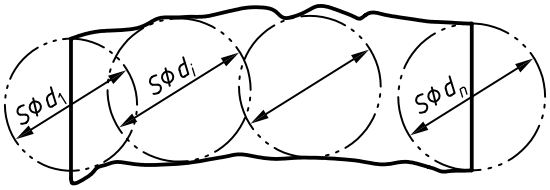
Note 2 to entry: The spherical size does not apply to spheres.

Note 3 to entry: See Figure 2 for examples of spherical sizes. Figure 2 a) shows an extracted feature under consideration, a cylinder which can be either internal or external.



a) Extracted feature under consideration

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b) Spherical sizes

Key

Sød diameter of the maximum inscribed sphere

Figure 2 — Examples of spherical sizes

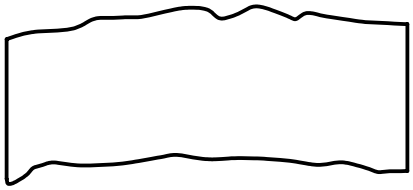
3.6.3
linear section size

global linear size (3.7) for a given section of the extracted integral feature of *linear size* (3.2)

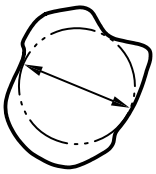
Note 1 to entry: A linear section size is a global linear size for a given section and is a *local linear size* (3.6) for the entire feature of linear size because it has different results of evaluation along the feature of linear size.

Note 2 to entry: On an extracted feature of linear size, which is a cylindrical surface, it is possible to define an infinite number of cross-sections in which the diameter of the associated circle can be defined (with a specific association criterion). This is a linear section size.

Note 3 to entry: See Figure 3 for an example of linear section size. Figure 3 a) shows an extracted feature under consideration, a cylinder which can be either internal or external. Figure 3 b) shows a linear section size obtained from a global linear size with maximum inscribed criterion (other criteria are possible).



a) Extracted feature under consideration



b) Linear section size obtained from a global linear size

NOTE The linear section size of Figure 3 b) in each cross-section is given by the diameter of the maximum inscribed circle defined in that cross-section.

Figure 3 — Example of linear section size

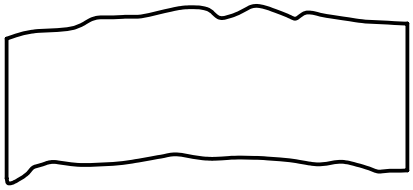
3.6.4
linear portion size

global linear size (3.7) for a given portion of the extracted feature of *linear size* (3.2)

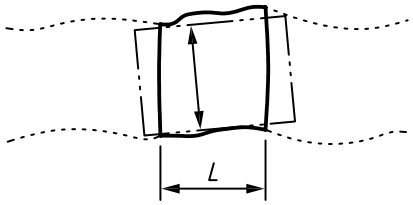
Note 1 to entry: A linear portion size is a global linear size for a given portion and is a *local linear size* (3.6) for the entire feature of linear size because it has different results of evaluation along the feature of linear size.

Note 2 to entry: See Figure 4 for an example of linear portion size. Figure 4 a) shows an extracted feature under consideration, a cylinder which can be either internal or external. Figure 4 b) shows a linear portion size obtained from a global linear size with maximum inscribed criterion (other criteria are possible).

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a) Extracted feature under consideration



b) Linear portion size obtained from a global linear size

Key

L considered length of the portion of the cylinder

NOTE Only a portion of length *L* of the extracted feature is considered.

Figure 4 — Example of linear portion size

3.7
global linear size
size characteristic (3.3) having a unique value along and around a feature of *linear size* (3.2)

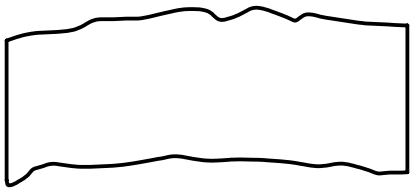
Note 1 to entry: A global linear size can be for a section, for a portion, or for the whole feature of linear size. See *linearsection size* (3.6.3) and *linearportion size* (3.6.4).

Note 2 to entry: In Figures 5, 6, 7 and 8, examples of global linear sizes are shown.

3.7.1
least-squares size
global linear size (3.7) for which an associated integral feature is established from the extracted integral feature(s) with the total least-squares objective function without constraint

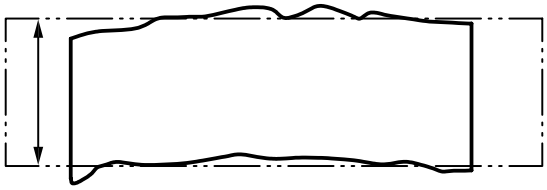
Note 1 to entry: In this document, "total least-squares" objective function is referred to only as "least-squares". This objective function minimizes the sum of the squares of distances existing between the associated integral feature and the extracted integral feature, see ISO 4351.

Note 2 to entry: See Figure 5 for an example of least-squares size. Figure 5 a) shows an extracted feature under consideration, which can be either an internal or external feature and either a cylinder or two parallel opposite planes.



a) Extracted feature under consideration

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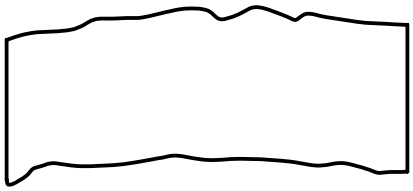
b) Least-squares size

Figure 5 — Example of least-squares size

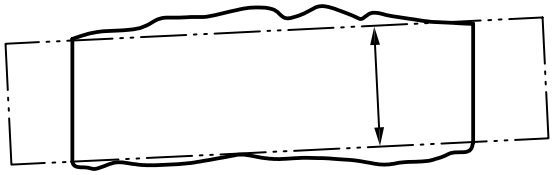
3.7.2
maximum inscribed size
global linear size (3.7) for which an associated integral feature is established from the extracted integral feature(s) with the maximum inscribed criterion

Note 1 to entry: In the case of an internal feature of *linear size* (3.2), the maximum inscribed size was previously called "mating size for an internal feature". It maximizes the size of the associated integral feature that is inscribed in the extracted integral feature.

Note 2 to entry: See Figure 6 for an example of maximum inscribed size. Figure 6 a) shows an extracted feature under consideration, which can be either an internal or external feature and either a cylinder or two parallel opposite planes.



a) Extracted feature under consideration



b) Maximum inscribed size

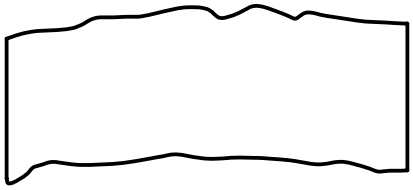
Figure 6 — Example of maximum inscribed size

3.7.3
minimum circumscribed size
global linear size (3.7) for which an associated integral feature is established from the extracted integral feature(s) with the minimum circumscribed criterion

Note 1 to entry: In the case of an external feature of *linear size* (3.2), the minimum circumscribed size was previously called "mating size for an external feature". It minimizes the size of the associated integral feature that is circumscribed to the extracted integral feature.

Note 2 to entry: See Figure 7 for an example of minimum circumscribed size. Figure 7 a) shows an extracted feature under consideration, which can be either an internal or external feature and either a cylinder or two parallel opposite planes.

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a) Extracted feature under consideration



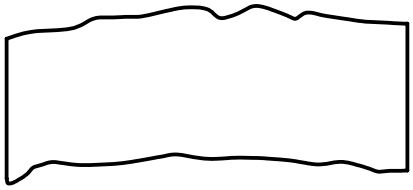
b) Minimum circumscribed size

Figure 7 — Example of minimum circumscribed size

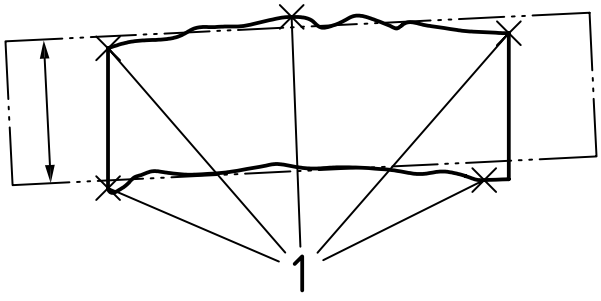
3.7.4
minimax size
Chebyshev size
global linear size (3.7) for which an associated integral feature is established from the extracted integral feature(s) with the minimax objective function and no material constraint

Note 1 to entry: The minimax objective function without constraint minimizes the maximum value of the set of distances between the points of the extracted integral feature and the associated integral feature without material constraint.

Note 2 to entry: See Figure 8 for an example of minimax size. Figure 8 a) shows an extracted feature under consideration, which can be either an internal or external feature and either a cylinder or two parallel opposite planes.



a) Extracted feature under consideration



b) Minimax size

Key

1 places with the same minimized maximum deviation

Figure 8 — Example of minimax size

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3.7.5
calculated size
size (3.1) obtained by using a mathematical formula that determines an intrinsic characteristic of a feature from one or several other dimensions of the same feature

Note 1 to entry: The calculated size is only defined for cylinders in this document.

3.7.5.1
circumference diameter
<of an extracted cylinder> *calculated size* (3.7.5) giving the diameter, *d*, obtained from the following formula:

$$d = \frac{C}{\pi}$$

where *C* is the length of the extracted and filtered integral line in a cross-section normal to the axis of the least-squares associated cylinder

Note 1 to entry: See Figure 9, which shows an example of circumference diameter.

Note 2 to entry: The circumference diameter is a *linearsection size* (3.6.3).

Note 3 to entry: In cases where the feature is non-convex, the circumference diameter can be larger than the minimum circumscribed diameter.

Note 4 to entry: A filter that builds a continuous line reduces the specification ambiguity in this case.



a) **b)**

Key

E extracted and filtered integral line in a cross-section, of length *C*

d circumference diameter, equal to *C* divided by π

Figure 9 — Example of circumference diameter

3.7.5.2
area diameter
<of an extracted cylinder> *calculated size* (3.7.5) giving the diameter, *d*, obtained from the following formula:

$$d = \sqrt{\frac{4A}{\pi}}$$

where *A* is the area limited by the extracted and filtered integral line of a cross section normal to the axis of the least-squares associated cylinder

Note 1 to entry: See Figure 10, which shows an example of area diameter.

Note 2 to entry: The area diameter is a *linearsection size* (3.6.3).

Note 3 to entry: A filter that builds a continuous line reduces the specification ambiguity in this case.

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a) b)

Key

A area inside the extracted and filtered integral line

d area diameter, calculated from *A*

Figure 10 — Example of area diameter

3.7.5.3
volume diameter
<of an extracted cylinder> *calculated size* (3.7.5) giving the diameter, *d*, obtained from the following formula:

$$d = \sqrt{\frac{4V}{\pi L}}$$

where

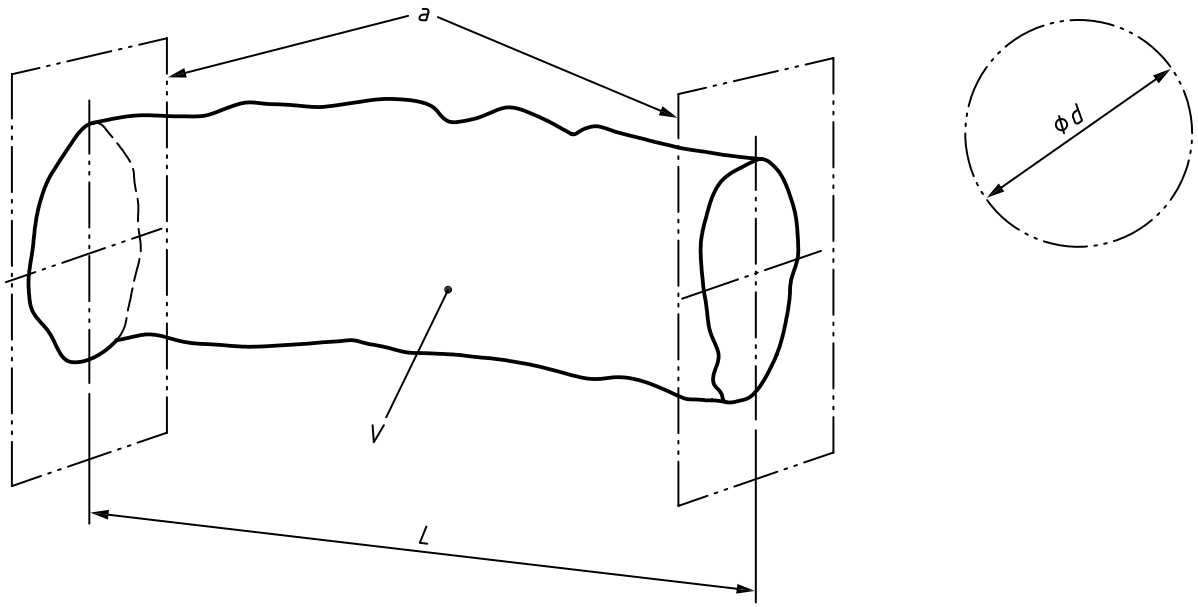
L is the distance between two parallel planes perpendicular to the axis of the least-squares associated cylinder, *L* being the maximum distance possible such that the two parallel planes contain a complete section of the feature;

V is the volume limited by the extracted integral cylinder and the two parallel planes.

Note 1 to entry: See Figure 11 for an example of volume diameter.

Note 2 to entry: The volume diameter is a *global linear size* (3.7) for the complete toleranced feature of *linear size* (3.2). It can be a *local linear size* (3.6) when it is a *linearportion size* (3.6.4).

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Key

V volume of the extracted integral cylinder

L length of the cylinder

d volume diameter, calculated from *V* and *L*

[a] Two parallel planes perpendicular to the axis of the least-squares associated cylinder with the minimum distance between them and containing a complete section of the feature.

Figure 11 — Example of volume diameter

3.7.6
statistical size
size characteristic (3.3) defined mathematically from a homogeneous set of values of a *local linear size* (3.6)

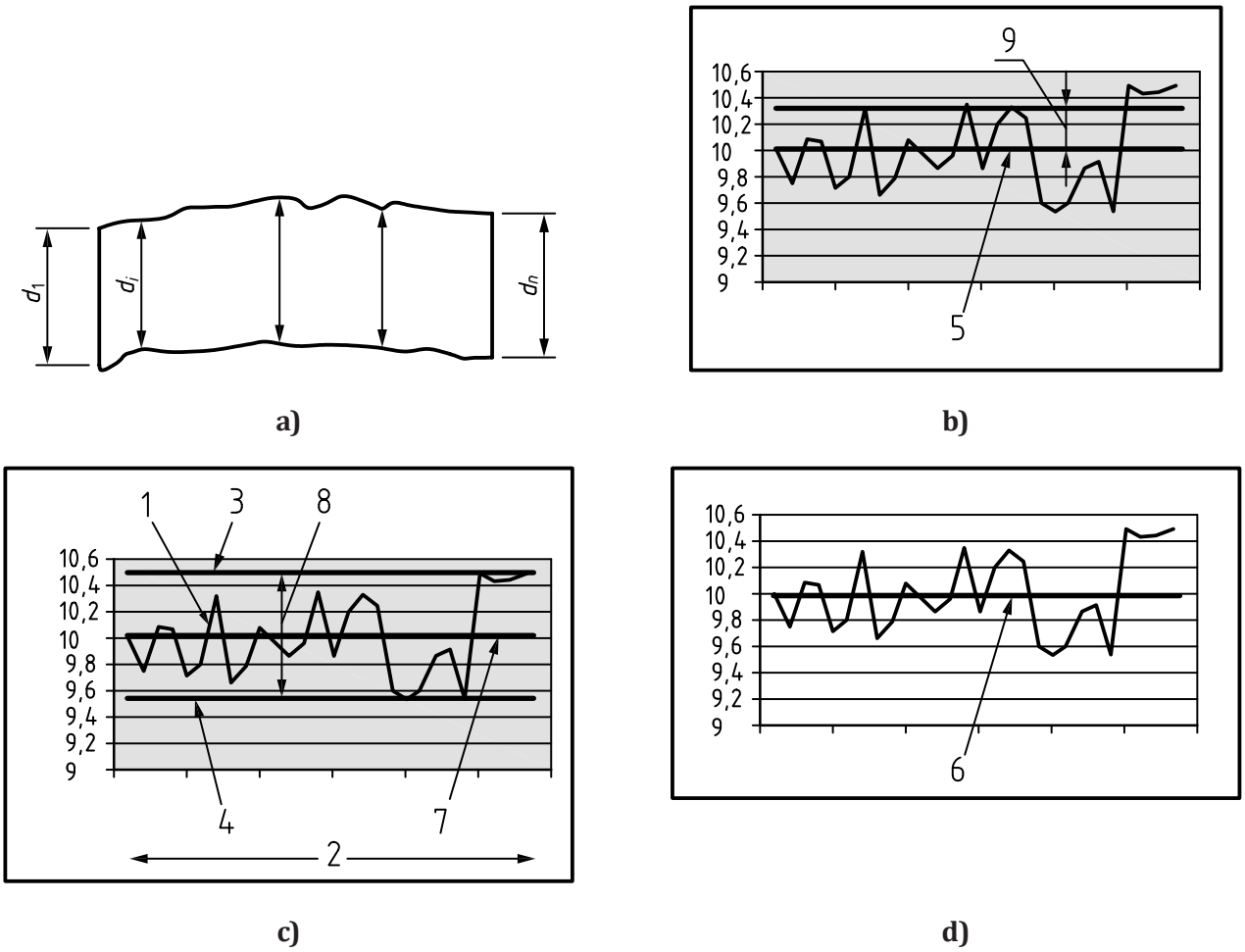
Note 1 to entry: A statistical size can be used to define a *global linear size* (3.7) from a local linear size [*two-point size* (3.6.1), *spherical size* (3.6.2), *linearsection size* (3.6.3) and *linearportion size* (3.6.4)].

Note 2 to entry: A statistical size can be used to define a local linear size from another local linear size, e.g. to define a statistical linear section size from a two-point size taken in the section.

Note 3 to entry: The different types of statistical sizes defined in this document are illustrated in Figure 12.

Note 4 to entry: Annex C shows an example of a statistical size.

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Key

1	set of values of linear section sizes	6	median size (= 9,969)
2	position along the axis	7	mid-range size (= 10,020)
3	maximum size (= 10,497)	8	range of sizes (= 0,955)
4	minimum size (= 9,542)	9	standard deviation of sizes (=0,301)
5	average size (= 10,011)	d_i	values of local linear size

Figure 12 — Example of statistical sizes based on linear section sizes

3.7.6.1
maximum size
statistical size (3.7.6) defined as the maximum of the set of values of a *local linear size* (3.6)

3.7.6.2
minimum size
statistical size (3.7.6) defined as the minimum of the set of values of a *local linear size* (3.6)

3.7.6.3
average size
statistical size (3.7.6) defined as the average of the set of values of a *local linear size* (3.6)

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3.7.6.4
median size
statistical size (3.7.6) defined as the median value of the set of values of a *local linear size* (3.6)

Note 1 to entry: The median value allows the population of local linear size values to be split into two equal portions (50 % above and 50 % below). Depending on the function of repartition of the population, the median size and the average size can be identical or different.

3.7.6.5
mid-range size
statistical size (3.7.6) defined as the mean of the maximum and the minimum of the set of values of a *local linear size* (3.6)

3.7.6.6
range of sizes
statistical size (3.7.6) defined as the difference between the maximum and the minimum of the set of values of a *local linear size* (3.6)

3.7.6.7
standard deviation of sizes
statistical size (3.7.6) defined as the standard deviation of the set of values of a *local linear size* (3.6)

3.8
envelope requirement
requirement which specifies both the least material limit of the *size* (3.1) on the *two-point size* (3.6.1) and the maximum material limit of the size on the *maximum inscribed size* (3.7.2) or the *minimum circumscribed size* (3.7.3)

Note 1 to entry: See Clause 9.

3.9
common toleranced feature of linear size
several separate single features of *linear size* (3.2) on which a common tolerance is applied

Note 1 to entry: See 8.3.

3.10
united feature of linear size
set of two or more single integral features considered as one feature of *linear size* (3.2)

Note 1 to entry: A united feature of linear size is a sub-type of united feature. A united feature can be an integral feature which is not a feature of linear size.

Note 2 to entry: See 8.4.

3.11
intersection plane
plane, established from an extracted feature of the workpiece, identifying one or more lines on extracted surfaces (integral or median) or one or more points on extracted lines (integral or median)

Note 1 to entry: The use of intersection planes makes it possible to define toleranced features independent of the view.

Note 2 to entry: For areal surface texture, the intersection plane can be used to define the orientation of the evaluation area, see ISO 25178-1.

[SOURCE: ISO 1101:2017, 3.2, modified — "a line on an extracted surface" changed to "one or more lines on extracted surfaces" and " a point on an extracted line" changed to " one or more points on extracted lines "]

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3.12
direction feature
<linear size> ideal feature, established from an extracted feature of the workpiece, identifying the direction of the *size characteristic* (3.3)

Note 1 to entry: See Clause 13.

4 General

4.1 Specification modifiers and symbols

Rule A**:** For the purposes of this document, the specification modifiers (see ISO 17450-2:2012, 3.4.2) in Tables 1 and 2 shall apply, except when the default size specification is used.

The use of these specification modifiers is described in Clauses 5 to 13. The presentation of graphical symbols shall follow the rules given in Annex A.

The presentation of indications of linear size specifications shall follow the rules given in Annex B.

Table 1 — Specification modifiers for linear size specifications

Modifier	Description	Reference
(LP)	Two-point size	3.6.1
(LS)	Spherical size	3.6.2
(GG)	Least-squares size	3.7.1
(GX)	Maximum inscribed size	3.7.2
(GN)	Minimum circumscribed size	3.7.3
(GC)	Minimax size	3.7.4
(CC)	Circumference diameter (calculated size)	3.7.5.1
(CA)	Area diameter (calculated size)	3.7.5.2
(CV)	Volume diameter (calculated size)	3.7.5.3
(SX)	Maximum size (statistical size)	3.7.6.1
(SN)	Minimum size (statistical size)	3.7.6.2
(SA)	Average size (statistical size)	3.7.6.3
(SM)	Median size (statistical size)	3.7.6.4
(SD)	Mid-range size (statistical size)	3.7.6.5
(SR)	Range of sizes (statistical size)	3.7.6.6
(SQ)	Standard deviation of sizes (statistical size)	3.7.6.7

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