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Technical product documentation and specification

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Contents

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 92, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 December 2011. It was prepared by Subcommittee TDW/4/8, *BS 8888 – Technical product specification*, under the authority of Technical Committee TDW/4, *Technical product realization*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 8888:2008, which is withdrawn.

Information about this document

This sixth edition of the standard is a full revision. It introduces relevant international standards published since the 2008 edition. It also incorporates more fully than previous editions some of the fundamental requirements of the key international standards relevant to the preparation of technical product specifications, such as BS EN ISO 1101 and BS EN ISO 5459. It is hoped that UK industry will find this edition of BS 8888 more user friendly than previous editions. It aims to help organizations better understand and implement the full complement of International Standards developed by ISO/TC 213, *Geometrical product specifications and verification*, and ISO/TC 10, *Technical product documentation*.

Relationship with other publications

The function of BS 8888 is to draw together, in an easily accessible manner, the full complement of international standards relevant to the preparation of technical product specifications. However, it is not the intention for BS 8888 to be a "stand-alone" standard. TDW/4 is responsible for a suite of related national standards which include the various parts of the BS 8887 series, BS 8889 [1)]and PD 68888, a new training document.

BS 8888 was taken up by the Ministry of Defence in 2006 as part of its DEF-STAN for defence project specification.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

All dimensions shown in the figures in this British Standard are in millimetres.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1) In development.

1 Scope

This British Standard implements the ISO system for technical product documentation and specification.

The ISO system is defined in a large number of interlinked and related international standards which are referenced from within BS 8888.

The purpose of this British Standard is to facilitate the use of the ISO system by providing:

- an index to the international standards which comprise the ISO system, referencing them according to their area of application;
- key elements of the ISO standards to facilitate their application;
- references to additional British and European Standards where they provide information or guidance over and above that provided by ISO standards; and
- commentary and recommendations on the application of the standards where this is deemed useful.

The requirements refer to International and European Standards which have been implemented as British Standards either in the BS EN, BS EN ISO, BS ISO series or as International Standards re-numbered as British Standards.

Annex A (normative) contains a list of normative references, indispensible for the application of this British Standard.

Annex B (informative) contains a list of informative references.

Annex C (normative) contains a set of examples of geometrical tolerances and associated requirements.

Annex D (normative) contains requirements for enhanced security.

Annex E (informative) provides a summary report on the concepts that have underwritten the development of technical product specification (TPS) and its primary constituent, geometrical product specification (GPS), to date and discusses some of the drivers for future change.

2 Normative references

Normative references are indispensable for the application of this document. A full list is contained in Annex A.

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply, together with those given in

BS EN ISO 10209	*Technical product documentation – Vocabulary - Terms relating to technical drawings, product definition and related products*
BS EN ISO 14660-1	*Geometrical product specification (GPS) – Geometrical features – Part 1: General terms and definitions*

3.1 date of acceptance

point in time at which all interested parties agree that the technical product specification is to be considered finalized to the extent that manufacturing can commence

NOTE 1 This might be identified by other terms, e.g. "date of issue".

*NOTE 2 For the implications of the date of acceptance see **4.2.3**.*

3.2 ISO GPS system
geometrical product specification and verification system developed in ISO by ISO/TC 213

3.3 technical product documentation (TPD)
means of conveying all or part of a design definition or specification of a product

3.4 technical product specification (TPS)
technical product documentation comprising the complete design definition and specification of a product for manufacturing and verification purposes

NOTE A TPS, which might contain drawings, 3-D models, parts lists or other documents forming an integral part of the specification, in whatever format they might be presented, might consist of one or more TPDs.

4 Standards underpinning BS 8888

4.1 Fundamental TPS principles

4.1.1 General

The following standards shall be applied as "global" standards in support of BS 8888.

ISO/IEC Guide 98-3	*Guide to the expression of uncertainty in measurement (GUM)*
ISO/IEC Guide 99	*International vocabulary of metrology – basic and general concepts and associated terms (VIM)*

The following principles shall always be applied where conformity with BS 8888 is claimed.

4.1.2 General principles of specification

A TPS shall document the criteria that the manufactured product has to satisfy.

NOTE 1 The TPS might include requirements of individual manufactured components, where necessary.

NOTE 2 The TPS might include additional information required for the manufacture, verification, maintenance and disposal of the product.

NOTE 3 Criteria might include requirements relating to the appearance, transportation, storage, maintenance, assembly, disassembly, recycling and disposal of the product, as well as its performance and reliability in use.

Sizes, geometrical relationships and tolerances which are necessary for the correct functioning or location of a component or assembly shall be specified through the use of datums, dimensions and tolerances.

NOTE 4 Selection of datum features which are not related to the function or location of a component or assembly results in the need for tighter tolerances.

A TPS shall provide sufficient information to avoid ambiguity of interpretation.

NOTE 5 A TPS is not complete if there is more than one possible interpretation of the specification.

A TPS shall provide sufficient information for the product to be manufactured, but shall not unnecessarily constrain manufacturing methods.

NOTE 6 A particular manufacturing process which has been tested and approved for the production of a safety-critical component is an example of a situation where there is a requirement to specify the manufacturing method.

A TPS shall provide sufficient information for the verification of each element of the specification, but shall not unnecessarily constrain verification methods.

A TPS shall provide all the information necessary for the manufacture and verification of the product, or state where that information can be found.

NOTE 7 This might be achieved through the use of notes and references to other standards or documents.

4.1.3 Acceptance date principle

A TPS shall always be interpreted according to those versions of standards which governed its interpretation on its acceptance date.

NOTE What is not specified in a TPS at the date of acceptance cannot be required.

4.1.4 Reference condition principle

Unless otherwise stated, all geometrical forms, sizes and tolerances for a work-piece given in a TPS shall be considered to apply at 20 °C.

NOTE 1 See BS EN ISO 1.

Unless otherwise stated, all geometrical sizes, forms and tolerances for a workpiece given in a TPS shall be considered to apply in the absence of any external forces (including gravity).

*NOTE 2 This is of particular importance when aligning and/or measuring large and/or flexible constructions. See **22.2**.*

4.2 Implied annotation

The following rules shall govern the use and interpretation of implied annotation on engineering drawings.

NOTE A dimension may be implied and not indicated on a drawing in the following circumstances, so long as there is no risk of misinterpretation.

a) Where two features are aligned, there is no requirement to indicate a linear dimension of 0 or an angular dimension of 0°.

b) Where two features are parallel to each other, there is no requirement to indicate an angular dimension of 0° or 180°.

c) Where two features are at 90° to each other, there is no requirement to indicate an angular dimension of 90°.

d) Where several features are equispaced around a pitch circle (see BS ISO 129-1), there is no requirement to indicate an angular dimension, although it might be advisable to do so. Terms such as "equispaced", "equally spaced", etc. shall not be used.

e) Where not otherwise indicated, holes are considered as through holes.

If the features concerned have their locations and/or orientations controlled through the use of geometrical tolerances, then the implied dimensions shall be taken as Theoretically Exact Dimensions (TEDs; see BS EN ISO 1101).

If the features concerned have their locations and/or orientations controlled through the use of +/– or limit tolerances, then the implied dimensions shall also be toleranced. In the absence of other indications, they shall be subject to a general tolerance, or else the TPS would remain incomplete.

Tolerances shall never be implied, and shall always be indicated.

Datums shall never be implied, and shall always be indicated.

Section 1: Technical product documentation

5 Types of documentation

5.1 General

*COMMENTARY ON **5.1***

The careful targeting of TPDs to known or intended users can greatly assist the accuracy with which the specification is converted into the final product.

While precision and avoidance of ambiguity shall always be paramount, the means employed to convey this information shall be seen to match the capability, or potential capability, of the available or achievable manufacturing facility.

NOTE Specification beyond this level is unlikely to produce satisfactory results and can often prove expensive, both in terms of the cost of the over-specification itself and in terms of inadequate or unacceptable product.

5.2 Presentation media

5.2.1 General

The presentation of the drawings shall conform to the following standards, as appropriate.

BS EN ISO 5457	*Technical product documentation – Sizes and layout of drawing sheets*
BS EN ISO 7200:2004	*Technical product documentation – Data fields in title blocks and document headers*
BS ISO 7573	*Technical drawings – Parts lists*

5.2.2 Format

Drawing sheets and other documents shall be presented in one of the following formats.

a) Landscape: intended to be viewed with the longest side of the sheet horizontal.

b) Portrait: intended to be viewed with the longest side of the sheet vertical.

NOTE Contrary to BS EN ISO 5457, A4 sheets may be used in landscape or portrait mode.

6 Drawing sheets

6.1 Sizes

As stated in the requirements of BS EN ISO 5457, the original drawing shall be made on the smallest sheet permitting the necessary clarity and resolution.

NOTE 1 The preferred sizes of the trimmed and untrimmed sheets as well as the drawing space of the main ISO-A series (see BS EN ISO 216) are given in Table 1.

NOTE 2 See BS EN ISO 5457 for more information about drawing sheets.

*NOTE 3 The range of sheet sizes chosen could be rationalized through the use of a variety of new scales. See Clause **8**.*

Table 1 **Sizes of trimmed and untrimmed sheets and the drawing space** A)

Designation	Trimmed sheet (T)		Drawing space		Untrimmed sheet (U)	
	a_1 B)	b_1 B)	a_2 ±0.5	b_2 ±0.5	a5 ±2	b5 ±2
A0 C)	841	1 189	821	1 159	880	1 230
A1	594	841	574	811	625	880
A2	420	594	400	564	450	625
A3	297	420	277	390	330	450
A4	210	297	180	277	240	330

A) Dimensions in millimetres.

B) For tolerances see BS EN ISO 216.

C) For sizes > A0 see BS EN ISO 216.

6.2 Graphical features

6.2.1 Title block

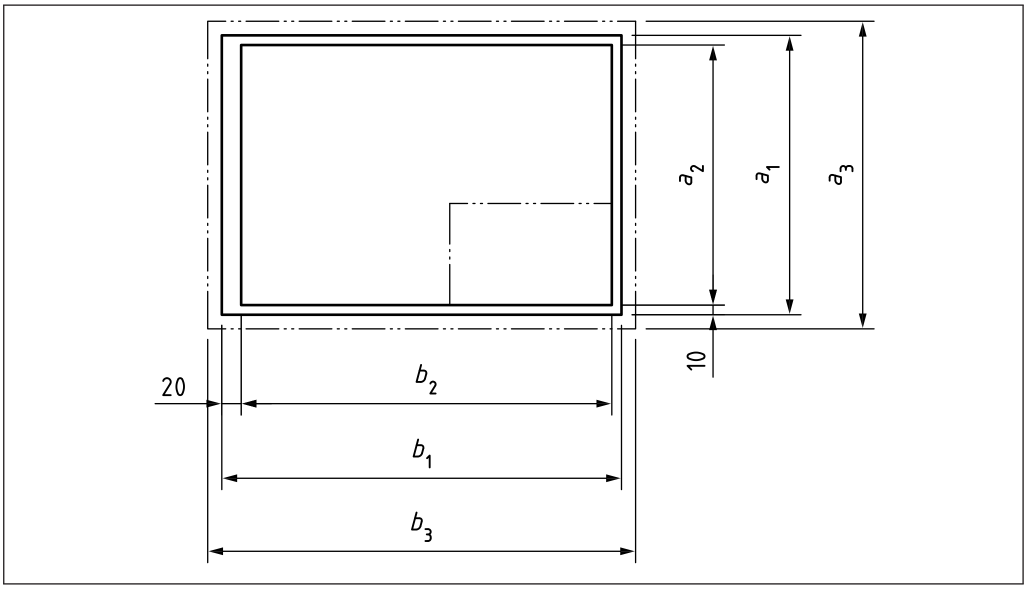
NOTE 1 For the dimensions and layout of title blocks, see BS EN ISO 7200.

Sizes A0 to A3 shall be used in landscape orientation only (Figure 1) and the location of the title block shall be situated in the bottom right-hand corner of the drawing space.

NOTE 2 A4 sheets may be used in landscape or portrait orientation.

For the size A4, the title block shall be situated in the bottom right-hand corner when used in landscape orientation, or the shorter (bottom) part of the drawing space when used in portrait orientation.

Figure 1 **Size A4 to A0**



6.2.2 Borders and frame

Borders enclosed by the edges of the trimmed sheet and the frame limiting the drawing space shall be provided with all sizes. The border shall be 20 mm wide on the left edge, including the frame and it can be used as a filing margin. All other borders shall be 10 mm wide.

The frame for limiting the drawing space shall be executed with continuous wide lines.

6.2.3 Grid reference system

The sheets shall be divided into fields in order to permit easy location of details, additions, revisions, etc. on the drawing. The individual fields shall be referenced from the top downwards with capital letters (I and O shall not be used) and from left to right with numerals. For the size A4, they shall be located only at the top and the right side.

The size of letters and characters shall be 3.5 mm. The length of the fields shall be 50 mm, starting at the axes of symmetry of the trimmed size (centring marks).

NOTE The number of fields depends on the size (see Table 2).

The differences resulting from the division shall be added to the fields at the corners. The letters and numerals shall be placed in the grid reference border, and shall be written in vertical characters according to BS EN ISO 3098-2.

The grid reference system lines shall be executed with continuous narrow lines.

Table 2 **Number of fields**

Designation	A0	A1	A2	A3	A4
Long side	24	16	12	8	6
Short side	16	12	8	6	4

6.3 Line types and line widths

6.3.1 Types of line

*COMMENTARY ON **6.3.1***

Table 3 shows the basic types of line. See BS EN ISO 128-20 for more information on lines.

6.3.2 Line width

According to the requirements of BS EN ISO 128-20, the width, *d*, of all types of line shall be one of the following depending on the type and size of drawing.

- 0,13 mm, 0,18 mm, 0,25 mm, 0,35 mm, 0,5 mm, 0,7 mm, 1 mm, 1,4 mm, 2 mm.

NOTE 1 The widths of extra wide, wide and narrow lines are in the ratio 4:2:1.

NOTE 2 For mechanical engineering drawings, four line types – continuous, dashed, chain (long-dashed dotted) and phantom (long-dashed double-dotted) – in two line thicknesses (typically 0,35 mm and 0,7 mm) are sufficient for most purposes.

The line width of any one line shall be constant throughout the whole line.

6.4 Colours

According to the requirements of BS EN ISO 128-20, lines shall be drawn black or white depending on the background. Other standardized colours may also be used for drawing standardized lines, and in this case, the meaning of the colours shall be explained.

Table 3 **Basic types**

No.	Representation	Description
01	――――――――――――――	continuous line
02	— — — — — — — — — — — — —	dashed line
03	— — — — — —	dashed spaced line
04	——— · ——— · ——— · ——— · ——— · ———	long-dashed dotted line
05	——— · · ——— · · ——— · · ——— · · ———	long-dashed double-dotted line
06	——— · · · ——— · · · ——— · · · ———	long-dashed triplicate-dotted line
07	- - - - - - - - - - - - - - - - - - - -	dotted line
08	——— – ——— – ——— – ——— – ———	long-dashed short-dashed line
09	——— – – ——— – – ——— – – ———	long-dashed double short-dashed line
10	— · — · — · — · — · — · —	dashed dotted line
11	— — · — — · — — · — — · —	double-dashed dotted line
12	— · · — · · — · · — · · —	dashed double-dotted line
13	— — · · — — · · — — · · —	double-dashed double-dotted line
14	— · · · — · · · — · · · —	dashed triplicate-dotted line
15	— · · · — · · · — · · · —	double-dashed triplicate-dotted line

7 Title block

7.1 General

*COMMENTARY ON **7.1***

A condition for the transfer and presentation of information is that data fields be defined with regard to field name, content of information and number of characters.

When document management systems are used, the conditions that apply to the data fields differ to a certain extent from those that apply in non-computerized document management. The same data field can, for example, be part of several different types of document simultaneously, as it is possible to process the contents by computer in connection with retrieval, revision, communication, etc.

For more information on title blocks, see BS EN ISO 7200.

If the functions of the system are to behave in a satisfactory way, the information shall be entered in the proper data field and in a correct manner.

NOTE For this reason, computer-based systems commonly contain more permanent data fields than paper-based systems.

The number of data fields in the title block shall be limited to a minimum, while other data fields shall be handled dynamically and presented outside the title block only when used, e.g. scale, projection symbol, general tolerance and surface texture requirements.

7.2 Data fields in the title block – Identifying data fields

The identifying data fields in the title block shall be in accordance with Table 4, which is from BS EN ISO 7200:2004.

Table 4 **Identifying data fields in the title block**

Subclause in BS EN ISO 7200:2004	Field name	Language dependent	Recommended number of characters	Obligation
5.1.2	legal owner	—	Unspecified	M
5.1.3	identification number	no	16	M
5.1.4	revision index	no	2	O
5.1.5	date of issue	no	10	M
5.1.6	segment/sheet number	no	4	M
5.1.7	number segments/sheets	no	4	O
5.1.8	language code	no	4 per language	O

M = mandatory

O = optional

Descriptive data fields shall be as specified in Table 5, which is taken from BS EN ISO 7200:2004.

Table 5 **Descriptive data fields in the title block**

Subclause in BS EN ISO 7200:2004	Field name	Language dependent	Recommended number of characters	Obligation
5.2.2	title	yes	25/30 [A)]	M
5.2.3	supplementary title	yes	2 × 25/30 [A)]	O

M = mandatory

O = optional

[A)] 30 to support two-byte-character language such as Japanese or Chinese.

Administrative data fields shall be as specified in Table 6, which is taken from BS EN ISO 7200:2004.

Table 6 **Administrative data fields in the title block**

Subclause in BS EN ISO 7200:2004	Field name	Language dependent	Recommended number of characters	Obligation
5.3.2	responsible department	no/yes [A)]	10	O
5.3.3	technical reference	no/yes [A)]	20	O
5.3.4	approval person	no/yes [A)]	20	M
5.3.5	creator	no/yes [A)]	20	M
5.3.6	document type	yes	30	M
5.3.7	classification/key words	no/yes [A)]	unspecified	O
5.3.8	document status	yes	20	O
5.3.9	page number	no	4	O
5.3.10	number of pages	no	4	O
5.3.11	paper size	no	4	O

M = mandatory

O = optional

[A)] "Yes" to support presentation in different types of alphabet.

7.3 Title block arrangement

*COMMENTARY ON **7.3***

For the position of title blocks on technical drawings, see BS EN ISO 5457. For text documents, there are no ISO requirements. For examples of title block arrangements for use on drawings as well as text documents, see Figures 2 and 3.

As specified by the requirements of BS EN ISO 7200, the total width shall be 180 mm to fit an A4 sheet, with the left margin being 20 mm and the right margin 10 mm.

Figure 2 **Title block in compact form**

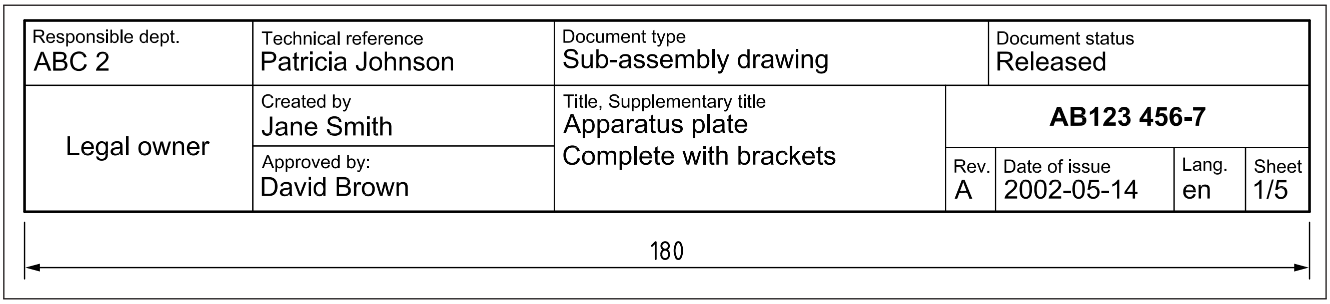
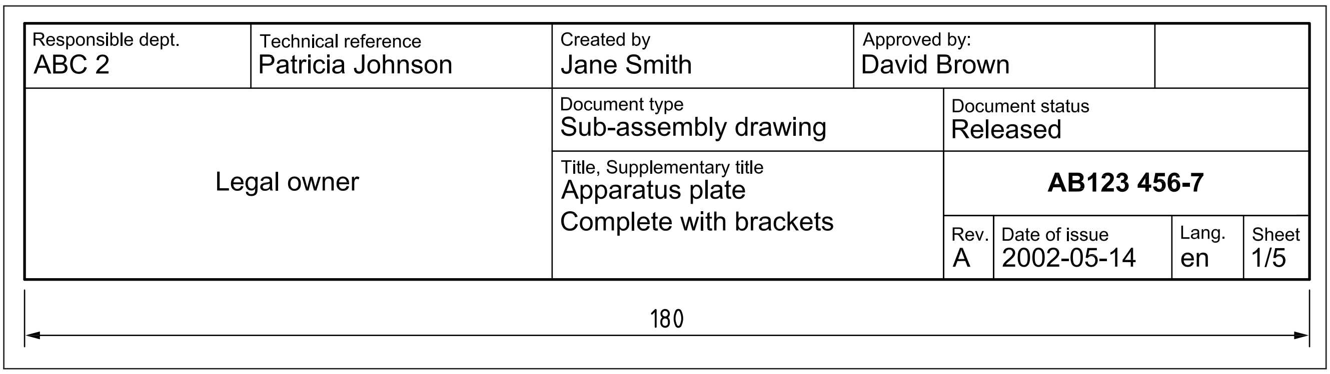


Figure 3 **Title block with person name fields on additional line**



8 Scales

8.1 General

The recommended scales for use on technical drawings shall be as specified in Table 7.

Table 7 **Scales**

Category	**Recommended scales**		
Enlargement scales	50:1	20:1	10:1
	5:1	2:1	
Full size			
Reduction scales	1:2	1:5	1:10
	1:20	1:50	1:100
	1:200	1:500	1:1 000
	1:2 000	1:5 000	1:10 000

The scale to be chosen for a drawing shall depend upon the complexity of the object to be depicted and the purpose of the representation. In all cases, the selected scale shall be large enough to permit easy and clear interpretation of the information depicted. The scale and the size of the object, in turn, shall decide the size of the drawing.

Details that are too small for complete dimensioning in the main representation shall be shown adjacent to the main representation in a separate detail view (or section) which is drawn to a larger scale.

NOTE 1 It is recommended that the scales in Table 7 are used wherever possible. However, with the advent of CAD systems and the ability to view drawings electronically at any size, the importance of using a standard range of scales has diminished. Where the recommended scales cannot be applied, intermediate scales may be selected.

3D models produced on CAD systems shall always be produced at 1:1.

NOTE 2 For more information on scales, see BS EN ISO 5455.

9 General tolerances

9.1 General

*COMMENTARY ON **9.1***

All features on component parts always have a size and a geometrical shape. For the deviation of size and for the deviations of the geometrical characteristics (form, orientation and location) the function of the part requires limitations which, when exceeded, impair this function.

The tolerancing on the drawing shall be complete to ensure that the elements of size and geometry of all features are controlled, i.e. nothing shall be implied or left to judgement in the workshop or in the inspection department.

NOTE 1 The use of general tolerances for size and geometry simplifies the task of ensuring that the prerequisites are met.

NOTE 2 See BS EN 22768 for more information on general tolerances.

9.2 General tolerances for linear dimensions

When use is made of BS EN 22768-1 (ISO 2768-1) for general tolerances, tolerances for dimensions shall be as given in Table 8, Table 9 and Table 10.

Table 8 **Permissible deviations for linear dimensions except for broken edges**

Tolerance class		Permissible deviations for basic size range							
Designation	**Description**	**0,5 A) up to 3**	**over 3 up to 6**	**over 6 up to 30**	**over 30 up to 120**	**over 120 up to 400**	**over 400 up to 1 000**	**over 1 000 up to 2 000**	**over 2 000 up to 4 000**
f	fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	—
m	medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
c	coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
v	very coarse	—	±0,5	±1	±1,5	±2,5	±4	±6	±8

A) For nominal sizes below 0,5 mm, the deviations shall be indicated adjacent to the relevant nominal size(s).

NOTE Values in millimetres.

Table 9 **Permissible deviations for broken edges (external radii and chamfer heights)**

Tolerance class		Permissible deviations for basic size range		
Designation	**Description**	**0,5 A) up to 3**	**over 3 up to 6**	**over 6**
f m	fine medium	±0,2	±0,5	±1
c v	coarse very coarse	±0,4	±1	±2

A) For nominal sizes below 0,5 mm, the deviations shall be indicated adjacent to the relevant nominal size(s).

NOTE Values in millimetres.

Table 10 **Permissible deviations of angular dimensions**

Tolerance class		Permissible deviations for ranges of lengths, in millimetres, of the shorter side of the angle concerned				
Designation	**Description**	**up to 10**	**over 10 up to 50**	**over 50 up to 120**	**over 120 up to 400**	**over 400**
f m	fine medium	±1°	±0°30'	±0°20'	±0°10'	±0°5'
c	coarse	±1°30'	±1°	±0°30'	±0°15'	±0°10'
v	very coarse	±3°	±2°	±1°	±0°30'	±0°20'

*COMMENTARY ON **9.2***

If reference to BS EN 22768-1 (ISO 2768-1) for general tolerances is inappropriate, general tolerance notes could be used to apply a common tolerance to many of the features on a drawing. The example shown in Figure 4 illustrates the wide field of application of this system.

Figure 4 **Examples of general tolerance notes**

TOLERANCE EXCEPT WHERE
OTHERWISE STATED ± X

TOLERANCE ON CAST THICKNESS
± X %

TOLERANCES EXCEPT WHERE
OTHERWISE STATED

SIZE		TOLERANCE
–	UP TO X	± A
OVER X	UP TO XX	± B
OVER XX	UP TO XXX	± C
OVER XXX	–	± D
ON ANGLES		± E

FOR TOLERANCE ON FORGING
DIMENSIONS SEE BS EN 10243-1

9.3 General geometrical tolerances

*COMMENTARY ON **9.3***

Due to the inherent risk of unintentionally over-specifying form and orientation controls that can result from the use of general geometrical tolerances, reference to BS EN ISO 22768-2 is inadvisable.

10 Conventions for arrangement of views on a TPD

10.1 General

Three main conventions shall be used for arranging the views on a TPD:

a) labelled views;

b) first angle orthographic projection;

c) third angle orthographic projection.

NOTE 1 The order of this list is not meant to indicate a preference.

NOTE 2 Other projection methods exist. See BS EN ISO 5456 (all parts).

10.2 Choice of views

When views (including sections and sectional views) are needed, these shall be selected according to the following principles.

a) The number of views (and sections and sectional views) shall be limited to the minimum necessary but shall be sufficient to fully delineate the object without ambiguity.

b) The need for hidden outlines and edges shall be avoided.

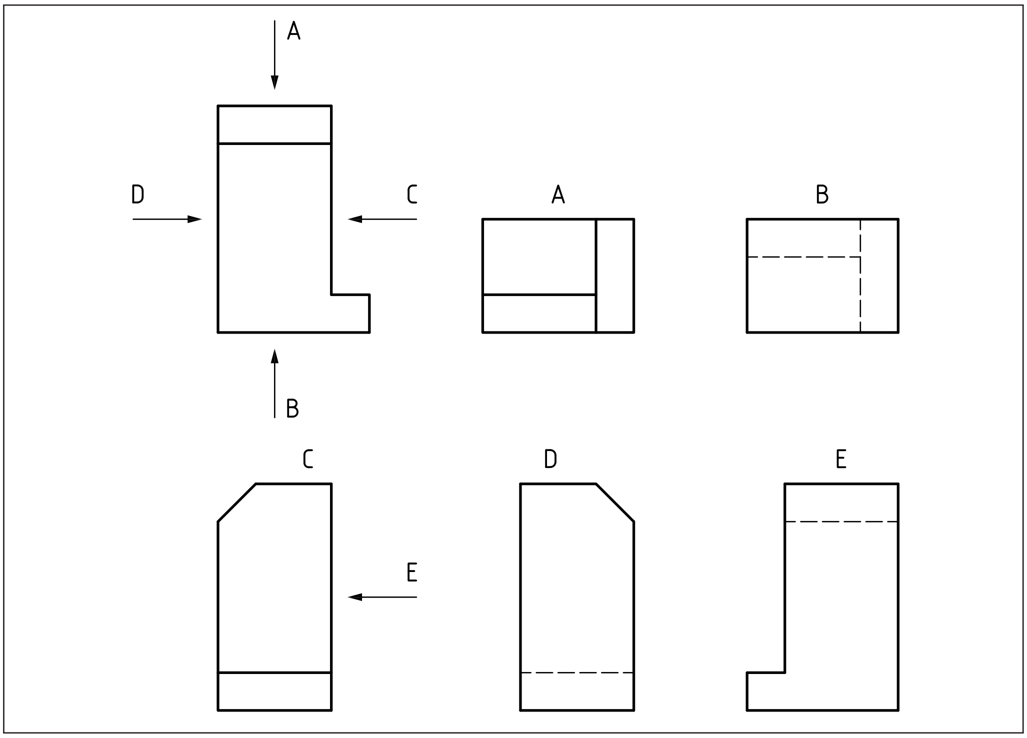
c) The unnecessary repetition of a detail shall be avoided.

10.3 Labelled view method

As specified by the requirements of BS ISO 128-30, the most informative view of an object shall be used as the front or principal figure, taking into consideration, for example, its functioning position, position of manufacturing or mounting. Each view, with the exception of the front or principal figure (view, plan, principal figure) shall be given clear identification with a capital letter, repeated near the reference arrow needed to indicate the direction of the viewing for the relevant view. Whatever the direction of viewing, the capital letter shall always be positioned in normal relation to the direction of reading, and be indicated either above or on the right side of the reference arrow.

The capital letters identifying the referenced views shall be placed immediately above the relevant views (see Figure 5).

Figure 5 **Labelled view method**



10.4 First angle projection method

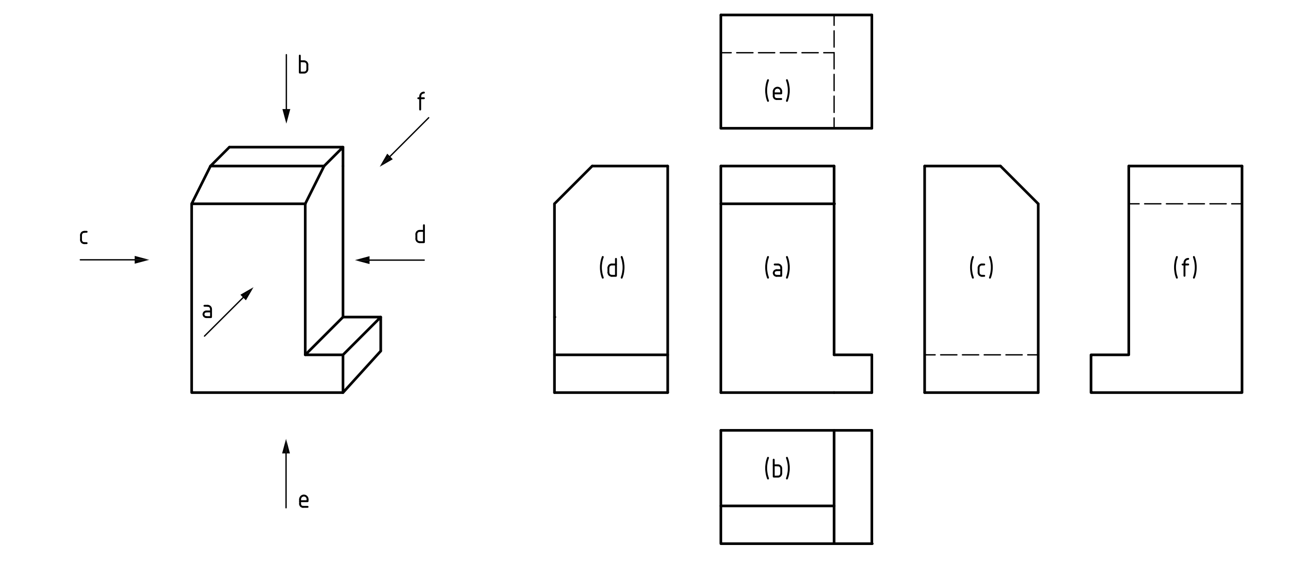
10.4.1 General

NOTE A more detailed description of the first angle projection method is to be found in BS ISO 128-30 and in BS EN ISO 5456-2.

With reference to the front view (a), the other views shall be arranged as follows (see Figure 6).

- The view from above (b) shall be placed underneath.
- The view from below (e) shall be placed above.
- The view from the left (c) shall be placed on the right.
- The view from the right (d) shall be placed on the left.
- The view from the rear (f) shall be placed on the left or right, as convenient.

Figure 6 **First angle projection method**

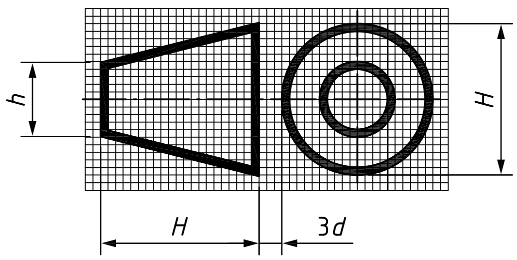


10.4.2 First angle projection method – Graphical symbol

As specified by the requirements of BS ISO 128-30, the graphical symbol for the first angle projection method shall be as shown in Figure 7.

The proportions and dimensions of this graphical symbol shall be as specified in BS ISO 128-30.

Figure 7 **First angle projection method – Graphical symbol**



10.5 Third angle projection method

10.5.1 General

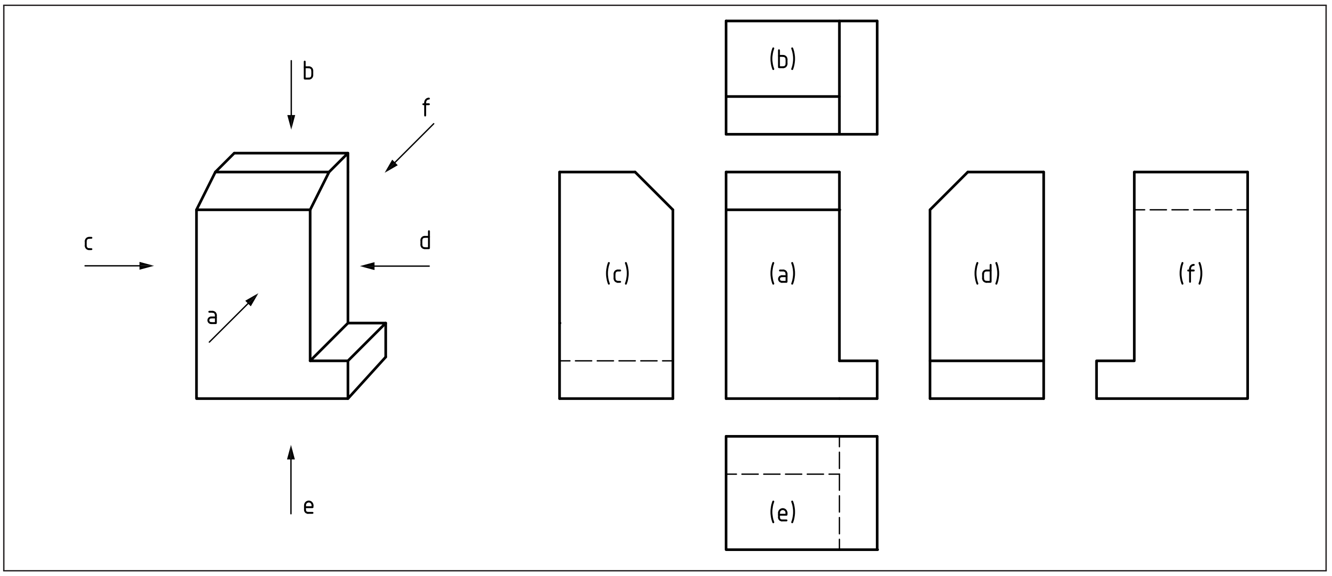
NOTE A more detailed description of the third angle projection method is to be found in BS ISO 128-30 and in BS EN ISO 5456-2.

10.5.2 Third angle projection method

With reference to the front view (a), the other views shall be arranged as follows (see Figure 8).

- The view from above (b) shall be placed above.
- The view from below (e) shall be placed underneath.
- The view from the left (c) shall be placed on the left.
- The view from the right (d) shall be placed on the right.
- The view from the rear (f) shall be placed on the left or right, as convenient.

Figure 8 **Third angle projection method**

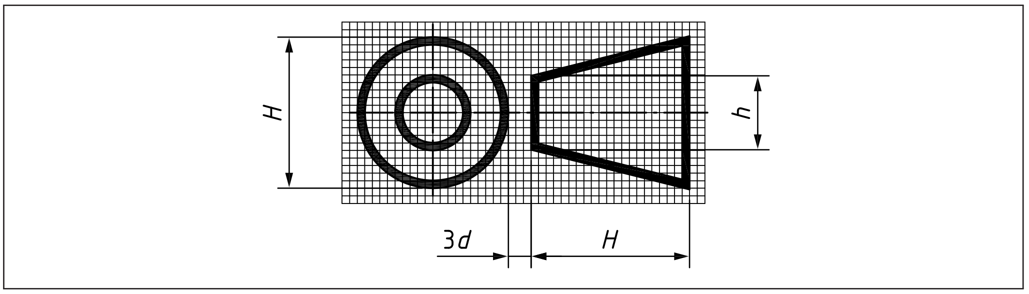


10.5.3 Third angle projection method – Graphical symbol

As specified by the requirements of BS ISO 128-30, the graphical symbol for the third angle projection method shall be as shown in Figure 9.

The proportions and dimensions of this graphical symbol shall be as specified in BS ISO 128-30.

Figure 9 **Third angle projection method – Graphical symbol**



11 Mechanical engineering drawings

11.1 General

As specified by the requirements of BS ISO 128-44, ribs, fasteners, shafts, spokes of wheels and the like shall not be cut in longitudinal sections, and shall therefore not be represented as sections.

NOTE 1 Like views, sections might be shown in a position other than that indicated by the arrows for the direction of their viewing.

NOTE 2 A section in one plane is shown in Figure 10.

NOTE 3 A section in two parallel planes is shown in Figure 11.

NOTE 4 A section in three contiguous planes in shown in Figure 12.

Figure 10 **Section in one plane**

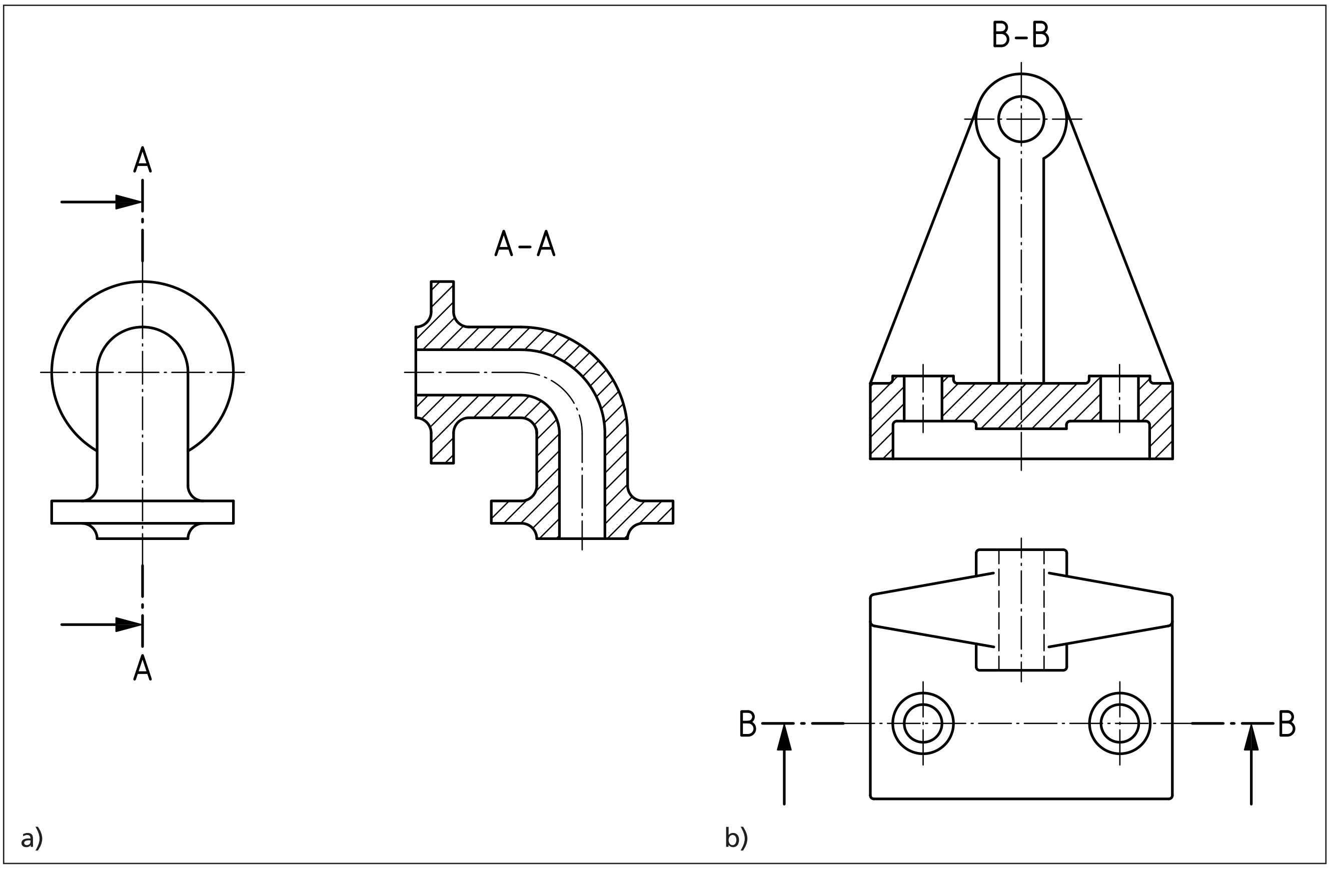


Figure 11 **Section in two parallel planes**

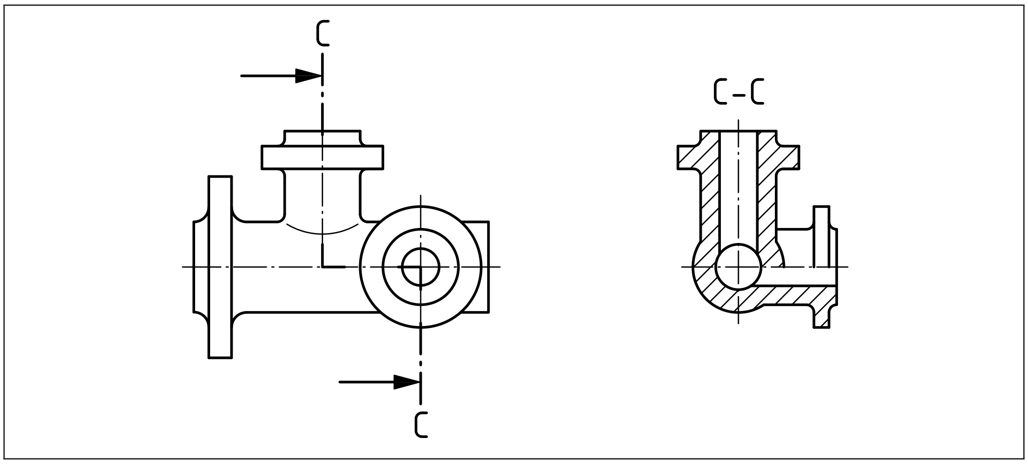
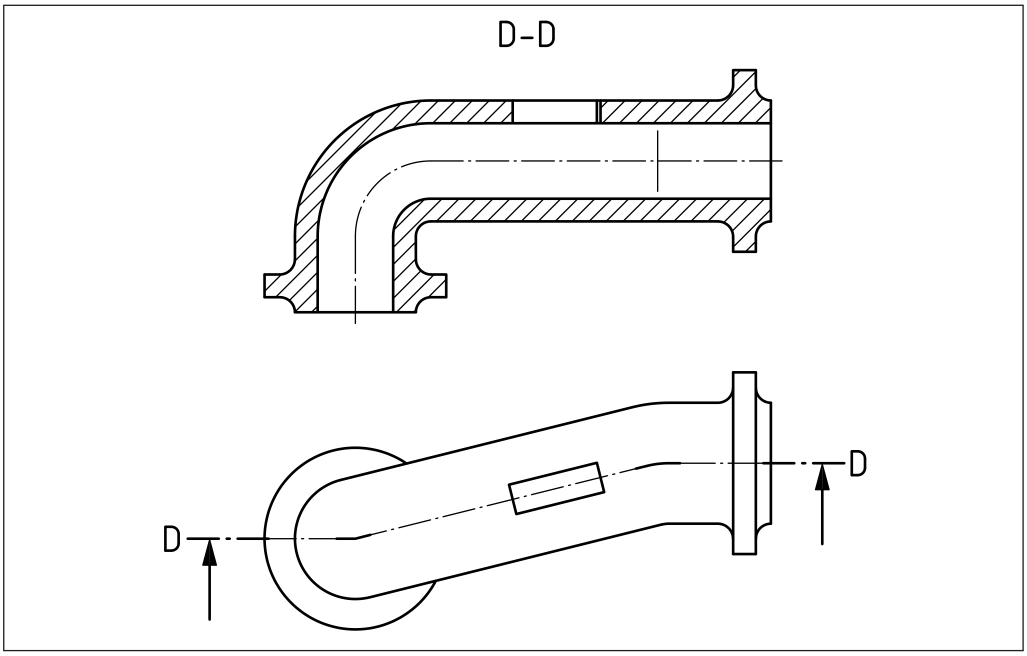


Figure 12 **Section in three contiguous planes**



12 Diagram

*COMMENTARY ON CLAUSE **12***

The function of a system, or the relationship between component parts, might be depicted in a diagram employing simplified representations, as recommended in the following standards.

BS 5070-1	*Engineering diagram drawing practice – Part 1: Recommendations for general principles*
BS 5070-3	*Engineering diagram drawing practice – Part 3: Recommendations for mechanical/fluid flow diagrams*
BS 5070-4	*Engineering diagram drawing practice – Part 4: Recommendations for logic diagrams*
BS EN 61082-2	*Preparation of documents used in electrotechnology – Part 2: Function-oriented diagrams*
BS EN ISO 3952-1	*Kinematic diagrams – Graphical symbols – Part 1*
BS EN ISO 3952-2	*Kinematic diagrams – Graphical symbols – Part 2*
BS EN ISO 3952-3	*Kinematic diagrams – Graphical symbols – Part 3*
BS ISO 15519-1	*Specification for diagrams for process industry – Part 1: General rules*

12.1 Designation

As specified by the requirements of BS EN ISO 5455, the complete designation of scale shall consist of the word "SCALE" (or its equivalent in the language used on the drawing) followed by the indication of its ratio as follows:

- SCALE 1 : 1 for full size;
- SCALE X : 1 for enlargement scales;
- SCALE 1 : X for reduction scales.

NOTE If there is no likelihood of misunderstanding, the word "SCALE" can be omitted.

12.2 Inscription

The designation of the scale used on the drawing shall be inscribed in the title block of the drawing.

Where it is necessary to use more than one scale on the drawing, the main scale only shall be inscribed in the title block, and all other scales adjacent to the item reference number of the part concerned, or adjacent to the reference letter of a detail view (or section).

13 Lines, arrows and terminators

13.1 Lines and terminators

Lines shall conform to the following standards, as appropriate.

BS EN ISO 128-20 *Technical drawings – General principles of presentation – Part 20: Basic conventions for lines*

BS EN ISO 128-21 *Technical drawings – General principles of presentation – Part 21: Preparation of lines by CAD systems*

BS ISO 128-22 *Technical drawings – General principles of presentation – Part 22: Basic conventions and applications for leader lines and reference lines*

BS ISO 128-23 *Technical drawings – General principles of presentation – Part 23: Lines on construction drawings*

BS ISO 128-24 *Technical drawings – General principles of presentation – Part 24: Lines on mechanical engineering drawings*

BS ISO 128-25 *Technical drawings – General principles of presentation – Part 25: Lines on shipbuilding drawings*

13.2 Lines, terminators and origin indicators

Arrows and terminators composed of lines shall conform to the following standard.

BS ISO 129-1 *Technical drawings – Indications of dimensions and tolerances – Part 1: General principles*

14 Lettering

14.1 General

Lettering shall conform to the following standards, as appropriate.

BS EN ISO 3098-0 *Technical product documentation – Lettering – Part 0: General requirements*

BS EN ISO 3098-2 *Technical product documentation – Lettering – Part 2: Latin alphabet, numerals and marks*

BS EN ISO 3098-3 *Technical product documentation – Lettering – Part 3: Greek alphabet*

BS EN ISO 3098-4 *Technical product documentation – Lettering – Part 4: Diacritical and particular marks for the Latin alphabet*

BS EN ISO 3098-5 *Technical product documentation – Lettering – Part 5: CAD lettering of the Latin alphabet, numerals and marks*

BS EN ISO 3098-6 *Technical product documentation – Lettering – Part 6: Cyrillic alphabet*

14.2 Notes

When a landscape-format drawing sheet is used in its normal orientation, with the title block at the bottom right-hand corner, notes shall be written with the text parallel to the long side of the sheet. When a landscape-format drawing sheet is used in portrait orientation, the title block shall be located at the left-hand side and notes shall be written with the text parallel to the short side of the sheet.

NOTE 1 Notes of a general nature should, wherever practicable, be grouped together and not distributed over the drawing. Notes relating to specific details should appear near the relevant feature, but not so near as to crowd the view.

NOTE 2 Underlining of notes is not recommended. Where emphasis is required, larger characters should be used.

NOTE 3 It is recommended that capital lettering is used wherever possible.

15 Projections

Projections shall conform to one of the following standards.

BS EN ISO 5456-2 *Technical drawings – Projection methods – Part 2: Orthographic representations*

BS EN ISO 5456-3 *Technical drawings – Projection methods – Part 3: Axonometric representations*

BS ISO 5456-4 *Technical drawings – Projection methods – Part 4: Central projection*

BS EN ISO 10209 *Technical product documentation*

NOTE BS EN ISO 5456-1 contains a survey of the various projection methods.

16 Views

16.1 General

Views shall conform to the following standards.

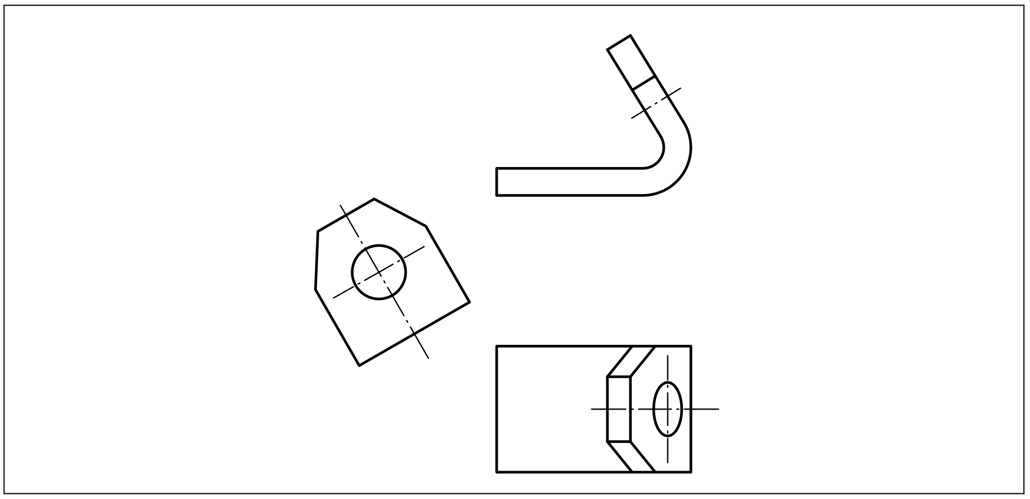
BS ISO 128-30 *Technical drawings – General principles of presentation – Part 30: Basic conventions for views*

BS ISO 128-34 *Technical drawings – General principles of presentation – Part 34: Views on mechanical engineering drawings*

16.2 Auxiliary views

Where true representation of features is necessary, but cannot be achieved on the orthographic views, the features shall be shown in projected auxiliary views. An example is shown in Figure 13.

Figure 13 **Auxiliary view showing true shape of inclined surface**



17 Sections

Sections shall conform to the following standards.

BS ISO 128-40	*Technical drawings – General principles of presentation – Part 40: Basic conventions for cuts and sections*
BS ISO 128-44	*Technical drawings – General principles of presentation – Part 44: Sections on mechanical engineering drawings*
BS ISO 128-50	*Technical drawings – General principles of presentation – Part 50: Basic conventions for representing areas on cuts and sections*

NOTE ISO 128-44 and ISO 128-50 contain presentational defects in some figures (e.g. line types, line thickness, terminators and letter heights), which have, unavoidably, been carried forward to the BS implementations. It is stressed that the text of these standards is technically correct and users should, therefore, regard the figures as illustrations only.

18 Symbols and abbreviations

18.1 General

Abbreviations (text equivalents) shall be the same in the singular and plural. Full stops shall not be used except where the abbreviation forms a word (e.g. NO. as an abbreviation for "number").

NOTE Where possible, abbreviations should be avoided (see ***18.2****).*

Symbols used for physical quantities and units of measurement shall conform to the following standards, as appropriate.

BS ISO 80000-1	*Quantities and units – Part 1: General*
BS ISO 80000-2	*Quantities and units – Part 2: Mathematical signs and symbols to be used in the natural sciences and technology*
BS ISO 80000-3	*Quantities and units – Part3: Space and time*
BS ISO 80000-4	*Quantities and units – Part4: Mechanics*
BS ISO 80000-5	*Quantities and units – Part 5: Thermodynamics*
BS EN ISO 80000-6	*Quantities and units – Part 6: Electromagnetism*

BS ISO 80000-7	*Quantities and units – Part 7: Light*
BS EN ISO 80000-8	*Quantities and units – Part 8: Acoustics*
BS ISO 80000-9	*Quantities and units – Part 9: Physical chemistry and molecular physics*
BS ISO 80000-10	*Quantities and units – Part 10: Atomic and nuclear physics*
BS ISO 80000-11	*Quantities and units – Part 11: Characteristic numbers*
BS ISO 80000-12	*Quantities and units – Part 12: Solid state physics*
BS EN 80000-13	*Quantities and units – Part 13: Information science and technology*
BS EN 80000-14	*Quantities and units – Part 14: Telebiometrics related to human physiology*

18.2 Standard symbols and abbreviations

*COMMENTARY ON **18.2***

In the existing environment of outsourcing across national borders, every effort is being made to make the use of GPS, independent of language through the adoption of standard symbology. It is for this reason that the continued use of abbreviations is deprecated. Where particular specification requirements cannot be expressed using the available GPS system, full text description should be employed. It is suggested that where such a requirement occurs frequently, this be drawn to the attention of the relevant ISO committee through the appropriate BSI Technical Committee.

For diagrams used in technical applications, a library of harmonized graphical symbols has been developed with close cooperation between ISO and IEC. This is published in the following series of standards and it is recommended that they be applied wherever practicable to improve the universal applicability of the TPS.

BS ISO 14617-1	*Graphical symbols for diagrams – Part 1: General information and indexes*
BS ISO 14617-2	*Graphical symbols for diagrams – Part 2: Symbols having general application.*
BS ISO 14617-3	*Graphical symbols for diagrams – Part 3: Connections and related devices*
BS ISO 14617-4	*Graphical symbols for diagrams – Part 4: Actuators and related devices*
BS ISO 14617-5	*Graphical symbols for diagrams – Part 5: Measurement and control devices*
BS ISO 14617-6	*Graphical symbols for diagrams – Part 6: Measurement and control functions.*
BS ISO 14617-7	*Graphical symbols for diagrams – Part 7: Basic mechanical components*
BS ISO 14617-8	*Graphical symbols for diagrams – Part 8: Valves and dampers.*
BS ISO 14617-9	*Graphical symbols for diagrams – Part 9: Pumps, compressors and fans*
BS ISO 14617-10	*Graphical symbols for diagrams – Part 10: Fluid power converters*
BS ISO 14617-11	*Graphical symbols for diagrams – Part 11: Devices for heat transfer and heat engines*

BS ISO 14617-12 *Graphical symbols for diagrams – Part 12: Devices for separating purification and mixing*

Symbols appropriate to technical product specification are provided and detailed throughout the suite of documents cross-referenced from this British Standard and these shall be used where appropriate.

NOTE 1 It is strongly recommended that abbreviations not be used.

Where, in particular technical fields, certain abbreviations are in common use and generally understood, it is accepted that these may continue to be used but new abbreviations shall not be introduced.

NOTE 2 Former practice has resulted in certain abbreviations becoming accepted as symbols and these should not be considered to provide precedence for the proliferation of abbreviations.

19 Representation of features

Conventions used for the representation of features shall conform to the following standards, as appropriate.

BS EN ISO 4063	*Welding and allied processes – Nomenclature of processes and reference numbers*
BS EN ISO 5261	*Technical drawings – Simplified representation of bars and profile sections*
BS EN ISO 5845-1	*Technical drawings – Simplified representation of the assembly of parts with fasteners – Part 1: General principles*
BS EN ISO 6410-1	*Technical drawings – Screw threads and threaded parts – Part 1: General conventions*
BS EN ISO 6410-2	*Technical drawings – Screw threads and threaded parts – Part 2: Screw thread inserts*
BS EN ISO 6410-3	*Technical drawings – Screw threads and threaded parts – Part 3: Simplified representation*
BS EN ISO 6411	*Technical drawings – Simplified representation of centre holes*
BS EN ISO 6413	*Technical drawings – Representation of splines and serrations*
BS ISO 13715	*Technical drawings – Edges of unidentified shape – Vocabulary and indications*
BS EN ISO 15785	*Technical drawings – Symbolic presentation and indication of adhesive, fold and pressed joints*
BS EN 22553	*Welded, brazed and soldered joints – Symbolic representation on drawings*

NOTE The BS ISO 128 series of standards covers the general subject of feature representation.

20 Representation of components

20.1 General

Conventions used for the representation of components shall conform to the following standards, as appropriate.

BS EN ISO 2162-1 *Technical product documentation – Springs – Part 1: Simplified representation*

BS EN ISO 2162-2	*Technical product documentation – Springs – Part 2: Presentation of data for cylindrical helical compression springs*
BS EN ISO 2162-3	*Technical product documentation – Springs – Part 3: Vocabulary*
BS EN ISO 2203	*Technical drawings – Conventional representation of gears*
BS 2917-1	*Graphic symbols and circuit diagrams for fluid power systems and components – Part 1: Specification for graphic symbols*
BS 3238-1	*Graphical symbols for components of servo-mechanisms – Part 1: Transductors and magnetic amplifiers*
BS 3238-2	*Graphical symbols for components of servo-mechanisms – Part 2: General servo-mechanisms*
BS EN ISO 5845-1	*Technical drawings – Simplified representation of the assembly of parts with fasteners – Part 1: General principles*
BS EN ISO 6410-1	*Technical drawings – Screw threads and threaded parts – Part 1: General conventions*
BS EN ISO 6410-2	*Technical drawings – Screw threads and threaded parts – Part 2: Screw thread inserts*
BS EN ISO 6410-3	*Technical drawings – Screw threads and threaded parts – Part 3: Simplified representation*
BS EN ISO 6412-1	*Technical drawings – Simplified representation of pipelines – General rules and orthogonal representation*
BS EN ISO 6412-2	*Technical drawings – Simplified representation of pipelines – Isometric projection*
BS EN ISO 6412-3	*Technical drawings – Simplified representation of pipelines – Terminal features of ventilation and drainage systems*
BS EN ISO 8826-1	*Technical drawings – Roller bearings – Part 1: General simplified representation*
BS EN ISO 8826-2	*Technical drawings – Roller bearings – Part 2: Detailed simplified representation*
BS EN ISO 9222-1	*Technical drawings – Seals for dynamic application – Part 1: General simplified representation*
BS EN ISO 9222-2	*Technical drawings – Seals for dynamic application – Part 2: Detailed simplified representation*

NOTE The BS ISO 128 series of standards covers the general subject of component representation.

20.2 Representation of moulded, cast and forged components

*COMMENTARY ON **20.2***

It is recommended that tolerances for the dimensions of plastics mouldings be applied in accordance with the system provided in BS 7010.

Dimensional tolerancing for metal and metal alloy castings shall conform to the following standards, as appropriate.

BS ISO 10135	*Geometrical product specifications (GPS) — Drawing indications for moulded parts in technical product documentation (TPD)*
BS EN ISO 8062-1	*Geometrical product specification (GPS) – Dimensional and geometrical tolerances for moulded parts – Vocabulary*

ISO/TS 8062-2	*Geometrical product specification (GPS) – Dimensional and geometrical tolerances for moulded parts – Part 2: Rules*
BS EN ISO 8062-3	*GPS – Dimensional and geometrical tolerances for moulded parts – General dimensional and geometrical tolerances and machine allowances for casting*

Section 2: Technical product specification

21 Fundamental principles

21.1 General

If a TPS is to be interpreted according to the rules of ISO GPS, the following statement shall be included in or near the title block:

"TOLERANCING ISO 8015"

NOTE This mandatory marking is a BS 8888 requirement, and not an ISO 8015 requirement. This is necessary to avoid possible misinterpretation of which system of standards govern the interpretation of a TPS.

21.2 Invocation principle

Once a portion of the ISO GPS system is invoked on a mechanical engineering product specification, the entire ISO GPS system shall be invoked, e.g. by reference to a relevant document.

"Unless otherwise indicated on the specification" means that it is indicated on the specification that this has been prepared in accordance with a certain standard; then that standard and not the ISO GPS system shall be used to interpret those elements of the specification which are covered by that standard.

NOTE 1 "Tolerancing ISO 8015" can optionally be indicated in or near the title block for information, but is not required to invoke the ISO GPS system.

NOTE 2 The ISO GPS system is defined in a hierarchy of standards that includes the following types of standards in the given order.

- *Fundamental GPS standards.*
- *General GPS standards.*
- *Complementary GPS standards.*

NOTE 3 See ISO/TR 14638.

That the "entire ISO GPS system is invoked" means that fundamental and global GPS standards shall apply and, consequently, that the reference temperature given in ISO 1 and the decision rules given in BS EN ISO 14253-1 shall apply, unless otherwise indicated.

NOTE 4 The purpose of the invocation principle is to provide the formal traceability for these GPS standards and rules.

The rules given in standards at a higher level in the hierarchy shall apply in all cases unless rules in standards at lower levels in the hierarchy specifically give other rules.

All rules given in fundamental GPS standards shall apply, in addition to those specifically given in general GPS standards, e.g. BS EN ISO 1101, except in the cases where the rules in the general GPS standard are explicitly different from the rules given in fundamental GPS standards and unless the rules in a specific complementary GPS standard give other rules that apply within its scope.

All rules given in fundamental and general GPS standards shall apply in addition to the rules specifically given in complementary GPS standards, e.g. BS EN 22768-1, except in the cases where the rules in the complementary GPS standard are explicitly different from the rules given in fundamental, and general GPS standards.

21.3 Definitive drawing principle

The drawing is definitive and all requirements shall be specified on the drawing using GPS symbology (with or without specification modifiers), associated default rules or special rules and references to related documentation, e.g. regional, national or company standards.

NOTE Consequently, requirements not specified on the drawing cannot be enforced.

A drawing might include requirements relating to several stages of completion of the product, in which case, it shall be indicated which stage each indication refers to, unless it is the final stage.

As part of the ISO GPS system, BS EN ISO 8015, and the principles and rules defined in it, shall apply to all product specifications where the ISO GPS system is invoked, even though it is not explicitly referenced in the drawing.

21.4 Feature principle

A workpiece shall be considered as made up of a number of features limited by natural boundaries. By default, every GPS specification for a feature or relation between features shall apply to the entire feature and each GPS specification shall apply only to one feature or one relation between features.

NOTE This default can only be overridden by explicit indications on the drawing.

21.5 Independency principle

By default, every GPS requirement for a feature or relation between features shall be fulfilled independently of other requirements, except when it is stated in a standard or by special indication (e.g. Ⓜ modifiers according to BS EN ISO 2692 or CZ) as part of the actual specification.

21.6 Decimal principle

Non-indicated decimals are zeros, and this principle shall apply to drawings as well as GPS standards.

NOTE 1 ±0,2 is the same as ±0,200 000 000 000 000 000 000 000 000 000 ... etc.

NOTE 2 10 is the same as 10,000 000 000 000 000 000 000 000 000 000 ... etc.

21.7 Default principle

A complete specification operator shall be indicated by using ISO basic GPS specifications.

NOTE The ISO basic GPS specification indicates that the requirement is based on the default specification operator.

21.8 Reference condition principle

By default, all GPS specifications shall apply at reference conditions. These include the standard temperature of 20 °C defined in ISO 1 and that the workpiece shall be free of contaminants.

Any additional or other conditions that apply, e.g. humidity conditions, shall be defined on the drawing.

21.9 Rigid workpiece principle

By default, a workpiece shall be considered as having infinite stiffness and all GPS specifications shall apply in the free state, undeformed by any external forces, including the force of gravity. Any additional or other conditions that apply shall be defined in the drawing.

*NOTE See, for example, **27.13** and BS ISO 10579.*

22 Dimensioning and tolerancing

22.1 Interpretations of limits of size for a feature-of-size

22.1.1 General

*COMMENTARY ON **22.1.1***

A feature-of-size might consist of two parallel plane surfaces, a cylindrical surface or a spherical surface, in each case defined with a linear size. A feature-of-size might also consist of two plane surfaces at an angle to each other (a wedge) or a conical surface, in each case defined with an angular size.

BS EN ISO 14405-1 states that limits of size control only the actual local sizes (two-point measurements) of a feature-of-size, and not its deviations of form (e.g. the roundness and straightness deviations of a cylindrical feature, or the flatness deviations of two parallel plane surfaces). Form deviations might be controlled by individually specified geometrical tolerances, general geometrical tolerances or through the use of the Envelope Requirement (where the maximum material limit of size defines an envelope of perfect form for the relevant surfaces see BS EN ISO 14405-1).

BS EN ISO 8015 defines the principle of independency, according to which each specified dimensional and geometrical requirement on a drawing is met independently, unless a particular relationship is specified. A relationship might be specified through the use of the Envelope Requirement or material condition modifiers (MMC or LMC).

Where no relationship is specified, any geometrical tolerance applied to the feature-of-size applies regardless of feature size, and the two requirements are treated as unrelated (see Figure 14). The limits of size do not control the form, orientation, or the spatial relationship between, individual features-of-size.

Consequently, if a particular relationship of:

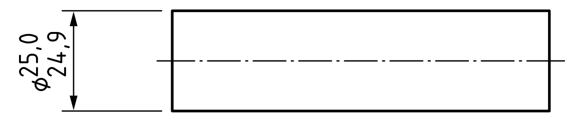
- *size and form; or*
- *size and location; or*
- *size and orientation;*

is required, it should be specified.

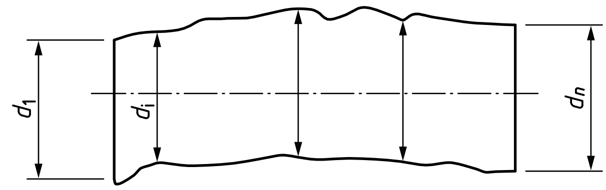
Limits of size for an individual feature-of-size shall be interpreted according to the principles and rules defined in the following standards.

BS EN ISO 8015:2011	*Geometrical product specifications (GPS) – Fundamentals – Concepts, principles and rules*
BS EN ISO 14405-1	*Geometrical product specifications (GPS) – Dimensional tolerancing – Part 1: Linear sizes (ISO 14405-1:2010)*
BS EN ISO 14660-1	*Geometrical Product Specifications (GPS) – Geometrical features – Part 1: General terms and definitions.*
BS EN ISO 14660-2	*Geometrical Product Specifications (GPS) – Geometrical features – Part 2: Extracted median line of a cylinder and a cone, extracted median surface, local size of an extracted feature*

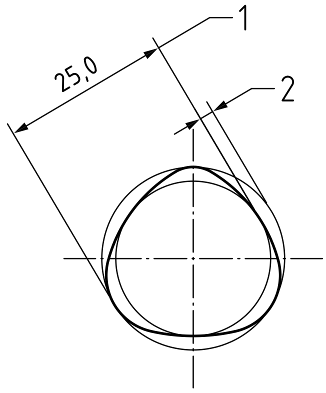
Figure 14 **Permissible interpretations when no form control is given on the drawing**



a) Drawing presentation



b) Permissible interpretation: straightness unconstrained



c) Permissible interpretation: roundness unconstrained

NOTE For any cross-section of the cylinder, there is no roundness control.

22.1.2 Limits of size with mutual dependency of size and form

*COMMENTARY ON **22.1.2***

Some national standards apply, or have applied, the Envelope Requirement to all features-of-size by default. As the Envelope Requirement has been the default, they have not used a symbol to indicate this requirement; rather they use a note to indicate when this is not required. This system of tolerancing is sometimes described as the Principle of Dependency, or the application of the Taylor Principle.

Standards which apply, or have applied, the Envelope Requirement by default include BS 308 and ASME Y14.5 [1] (the requirement that there is an envelope of perfect form corresponding to the Maximum Material Size of the feature is defined as Rule #1 in ASME Y14.5).

*ISO 2768-2 includes an option for marking drawings to indicate that the Envelope Requirement applies to all features of size on the drawing, but this marking is neither widely used nor well understood, and is not recommended. Use of ISO 2762-2 is in any case inadvisable (see **9.3**).*

ISO 14405-1 allows the default interpretation of size requirements to be changed for an TPS. A number of different possibilities are available, including the option of making the Envelope Requirement the default interpretation of size for the entire specification.

If the default interpretation of size is to be changed for a TPS, the following indication shall appear in or near the title block of each drawing:

SIZE ISO 14405

followed by the relevant modifier.

For example, if the Envelope Requirement is to be made the default interpretation of size requirements for the entire TPS, the indication shall be:

SIZE ISO 14405 Ⓔ

22.2 General

*COMMENTARY ON **22.2***

*It is the practice in the UK to leave a small gap between the extension line and the feature. In BS ISO 129-1:2004 the illustrated examples do not show a gap but **5.3** includes the text, "in certain technical fields, a gap between the feature and the beginning of the extension line is acceptable". The UK has always held to the view that for reasons of clarity a gap is preferable and given that in the revised standard the gap is permissible, it is intended that the current UK practice should be maintained.*

Dimensioning and tolerancing shall conform to the following standards, as appropriate.

BS ISO 129-1	*Technical drawings – Indications of dimensions and tolerances – Part 1: General principles*
BS ISO 406	*Technical drawings – Tolerancing of linear and angular dimensions*
BS EN ISO 1119	*Geometrical product specifications (GPS) – Series of conical tapers and taper angles*
BS EN ISO 1660	*Technical drawings – Dimensioning and tolerancing of profiles*
BS 1916-1	*Limits and fits for engineering – Part 1: Limits and tolerances*
BS 1916-2	*Limits and fits for engineering – Part 2: Guide to the selection of fits in BS 1916:Part 1*
BS 1916-3	*Limits and fits for engineering – Part 3: Recommendations for tolerances, limits and fits for large diameters*
BS ISO 3040	*Technical drawings – Dimensioning and tolerancing – Cones*
BS 3734-1	*Rubber – Tolerances for products – Part 1: Dimensional Tolerances*
BS 3734-2	*Rubber – Tolerances for products – Part 2*
BS 4500-4	*ISO limits and fits – Specification for system of cone (taper) fits for cones from C=1:3 to 1:500, lengths from 6 mm to 630 mm and diameters up to 500 mm*
BS 4500-5	*ISO limits and fits – Specification for system of cone tolerances for conical workpieces from C = 1:3 to 1:500 and lengths from 6 mm to 630 mm*
BS EN ISO 5458	*Geometrical Product Specifications (GPS) – Geometrical tolerancing – Positional tolerancing*
BS EN ISO 6410-1	*Technical drawings – Screw threads and threaded parts – Part 1: General conventions*
BS 6615 [2]	*Specification for dimensional tolerances for metal and metal alloy castings*
BS 7010	*Code of practice for a system of tolerances for the dimensions of plastic mouldings*

[2] Due to be superseded soon by ISO 8062 series.

BS EN ISO 7083	*Technical drawings – Symbols for geometrical tolerancing – Proportions and dimensions*
BS EN ISO 8015:2011	*Geometrical product specifications (GPS) – Fundamentals – Concepts, principles and rules*
BS ISO 10579	*Technical drawings – Dimensioning and tolerancing – Non-rigid parts*
BS ISO 13920	*Welding – General tolerances for welded constructions – Dimensions for lengths and angles – Shape and position*
BS EN 20286-1	*ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits*
BS EN 20286-2	*ISO system of limits and fits – Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

22.3 Presentation of decimals

22.3.1 General

Each group of three digits, counting from the decimal marker to the left and to the right, shall be separated from other digits by a small space (e.g. 12 345,067 8).

NOTE The use of a comma or a point for this purpose is deprecated, i.e. it is further recommended that separation of items in lists be effected by the use of a semi-colon.

22.3.2 Decimal marker

The decimal marker shall be a comma.

22.3.3 Non-indicated decimals in tolerances

Non-indicated decimals in a tolerance indication shall be taken as zeros, e.g. 0,2 is the same as 0,20000000000 . . .

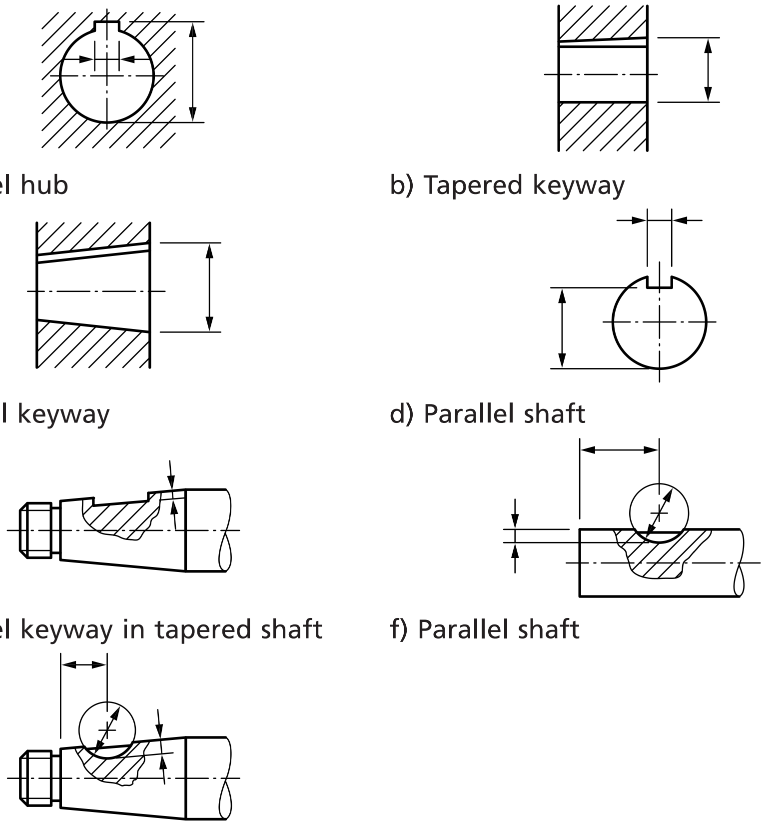
22.4 Keyways

Keyways in hubs or shafts shall be dimensioned by one of the methods shown in Figure 15.

NOTE 1 Limit tolerances and/or geometrical tolerances are also required.

NOTE 2 Further information on keys and keyways is given in BS 4235-1 and BS 4235-2.

Figure 15 **Dimensioning of keyways**



a) Parallel hub

b) Tapered keyway

c) Parallel keyway

d) Parallel shaft

e) Parallel keyway in tapered shaft

f) Parallel shaft

g) Tapered shaft

22.5 Screw threads

COMMENTARY ON ***22.5***

The following standards provide the definition for metric ISO screw threads.

BS 3643-1	*ISO metric screw threads – Part 1: Principles and basic data*
BS 3643-2	*ISO metric screw threads – Part 2: Specification for selected limits of size*
BS 4827	*Specification for ISO miniature screw threads – Metric series*
BS ISO 261	*ISO general purpose metric screw threads – General plan*
BS ISO 262	*ISO general purpose metric screw threads – Selected sizes for screws, bolts and nuts*
BS ISO 965-1	*ISO general purpose metric screw threads – Tolerances – Part 1: Principles and basic data*

Screw threads shall be specified according to functional requirement.

22.6 Methods of specifying tolerances

The necessary tolerances shall be specified in one or more of the following ways.

a) Separate indication on the drawing.

b) Reference to general tolerances noted on the drawing.

c) Reference to a standard containing general tolerances.

d) Reference to other documents.

23 Rules for parenthetic statements

Statements given in parentheses following the dimensional tolerance value are only for information and shall not constitute an integral part of the specification/requirement.

24 Features

COMMENTARY ON CLAUSE ***24***

A feature is a specific portion of the workpiece, such as a point, a line or a surface (see BS EN ISO 14660-1).

Features shall be classified in several different ways. The main classifications shall be:

a) integral features – features which consist of, or represent, surfaces on the workpiece;

b) features of size – integral features which have a size characteristic (two parallel opposed planes, cylinders, spheres, wedges, cones and toruses);

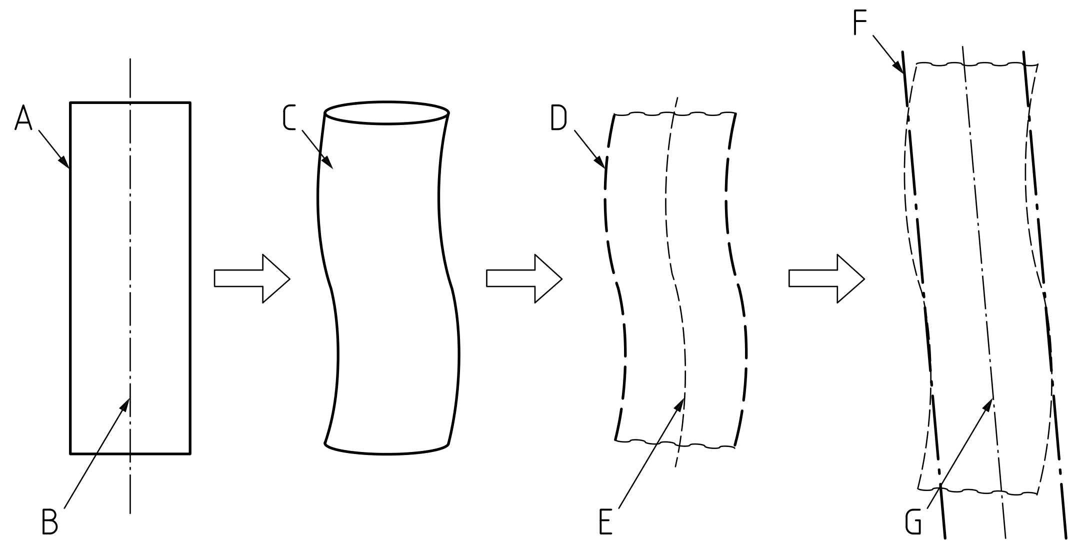
c) derived features – theoretical features, e.g. axes or median lines, which are derived from a feature of size (axis or median line, median plane or median surface, and centre points).

NOTE See Figure 16.

Geometrical features shall exist in three "worlds" or "states".

- The world of the specification, where features are represented in an ideal state. These features have perfect form, and perfect relationships with each other. Features in this world are known as nominal features.
- The world of the manufactured work-piece, the physical world. Features in this world are known as real features.
- The world of inspection, where a representation of a given work-piece is used through sampling of the workpiece by measuring instruments.

Figure 16 **Interrelationship of the geometrical feature definitions**



Key

A	Nominal integral feature	D	Extracted integral feature	G	Associated derived feature
B	Nominal derived feature	E	Extracted derived feature		
C	Real feature	F	Associated integral feature		

25 Datums and datum systems

25.1 General

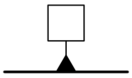
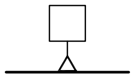
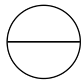
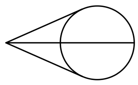
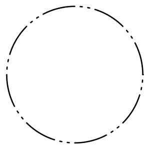
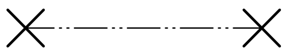
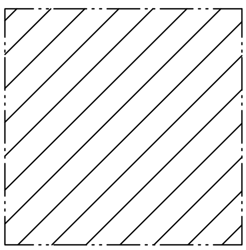
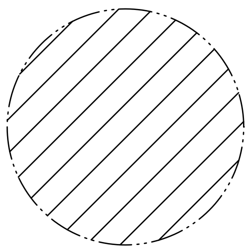
*COMMENTARY ON **25.1***

Geometrical Product Specification relies on the correct use of datums and datum systems in order to remove ambiguity from specifications. In BS EN ISO 5459, the operation and effect of datums is described in terms of degrees of freedom, invariance class and situation features. These concepts are explained in Annex D.

25.2 Symbols

Table 11 gives symbols which shall be used to identify the datum feature or datum target used to establish a datum.

Table 11 **Datum features and datum target symbols**

Description	**Symbol**	**BS EN ISO 5459 subclause**
Datum feature indicator	 	**7.2.1**
Datum feature letter	Capital letter (A, B, C, AA, etc.)	**7.2.2**
Single datum target frame		**7.2.3.2**
Movable datum target frame		**7.2.3.2**
Datum target point		**7.2.3.3**
Closed datum target line		**7.2.3.3**
Non-closed datum target line		**7.2.3.3**
Datum target area	 	**7.2.3.3**

25.3 Role of datums

Datums shall be established from real surfaces identified on a workpiece.

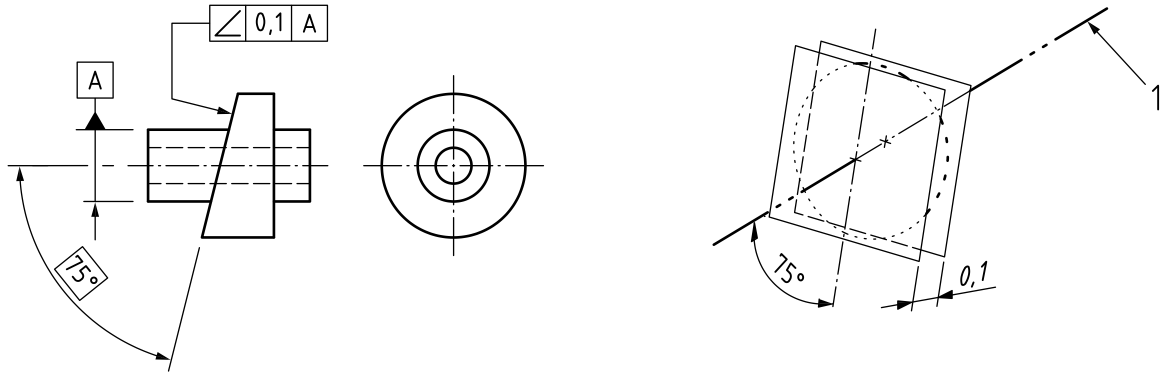
NOTE 1 The surfaces on a workpiece that are used to establish datums are known as datum features.

NOTE 2 Datums allow tolerance zones to be located or oriented (see Figure 17 and Figure 18) and virtual conditions to be defined (e.g. maximum material virtual condition Ⓜ according to BS EN ISO 2692). Datums can be seen as a means to lock degrees of freedom of a tolerance zone.

The number of degrees of freedom of the tolerance zone which are locked shall depend on the nominal shape of the features utilized to establish the datum or datum system; whether the datum is primary, secondary or tertiary; and on the toleranced characteristic indicated in the geometrical tolerance frame.

NOTE 3 The tolerance zone, which is the space between two parallel planes 0,1 mm apart, is constrained in orientation by a 75° theoretically exact angle from the datum. Here, the datum is the situation feature of a cylinder (axis of associated cylinder). See Figure 17.

Figure 17 **Example of tolerance zone constrained in orientation from a datum**

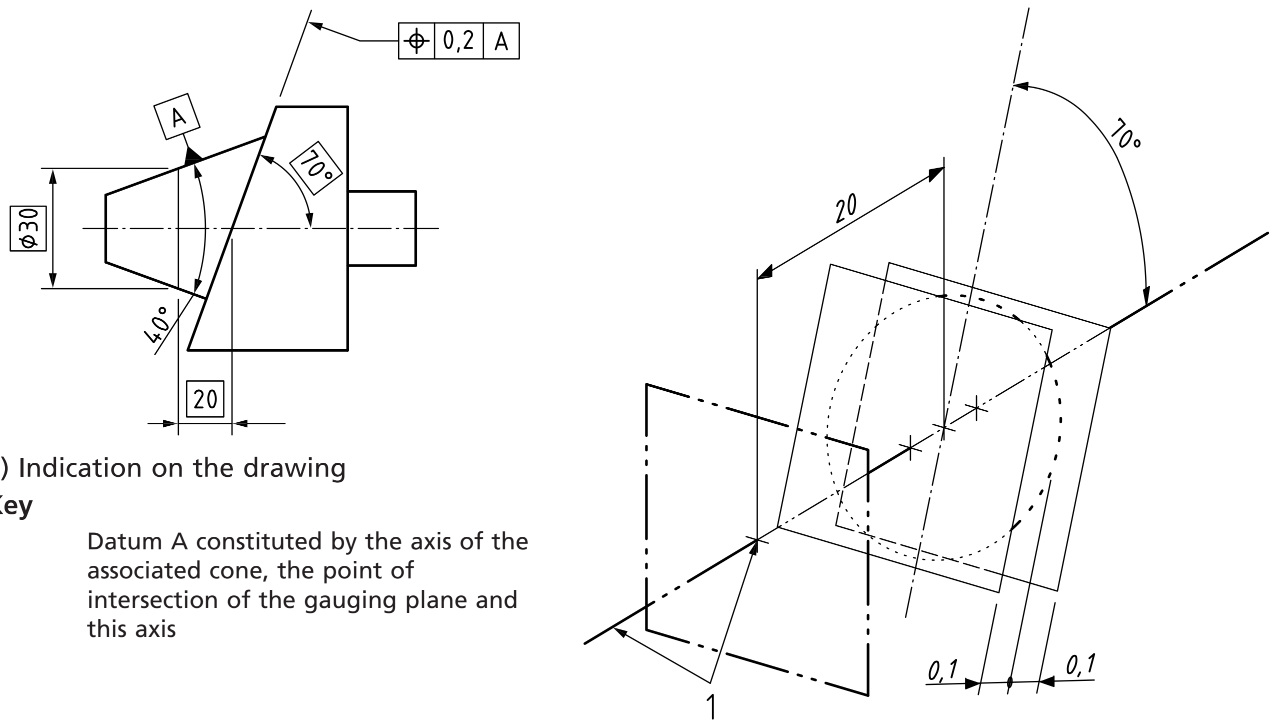


a) Indication on the drawing b) Illustration of tolerance zone

Key 1 Datum A, constituted by the axis of the associated cylinder

NOTE 4 The tolerance zone, which is the space between two parallel planes 0,2 mm apart, is constrained in orientation by a 70° angle from a datum, and in location by the distance 20 mm from the gauge plane positioned perpendicular to the axis of 40° cone where its local diameter is 30 mm. Here, the datum consists of the set of situation features of the cone with a fixed angle of 40°, i.e. the cone axis and the point of intersection between the gauge plane and that axis. See Figure 18.

Figure 18 **Examples of a tolerance zone constrained in location from a datum**



a) Indication on the drawing

Key

1 Datum A constituted by the axis of the associated cone, the point of intersection of the gauging plane and this axis

b) Illustration of tolerance zone

25.4 Datum concepts

25.4.1 General

Datums and datum systems shall be theoretically exact geometric features used together with TEDs to locate or orientate:

- tolerance zones for toleranced features; or
- virtual conditions, e.g. in the case of maximum material requirement (see BS EN ISO 2692).

A datum shall consist of a set of situation features for an ideal feature (feature of perfect form). This ideal feature is an associated feature which shall be established from the identified datum features of a workpiece.

NOTE 1 Datum features might be complete features, or identified portions thereof.

NOTE 2 One or more single features can be used to establish a datum. If only one single feature is used, it establishes a single datum. If more than one single feature is used, they can either be considered simultaneously to establish a common datum or in a predefined order to establish a datum system.

The datum feature(s) to be used for establishing each datum shall be designated and identified.

NOTE 3 Datums and datum systems are geometrical features, not coordinate systems. Coordinate systems can be built on datums.

25.4.2 Single datum established from a single feature

In order to derive the datum, the following sequence of operations is performed.

a) A partition to define the real integral surface corresponding to the nominal feature [see Figure 19 b)].

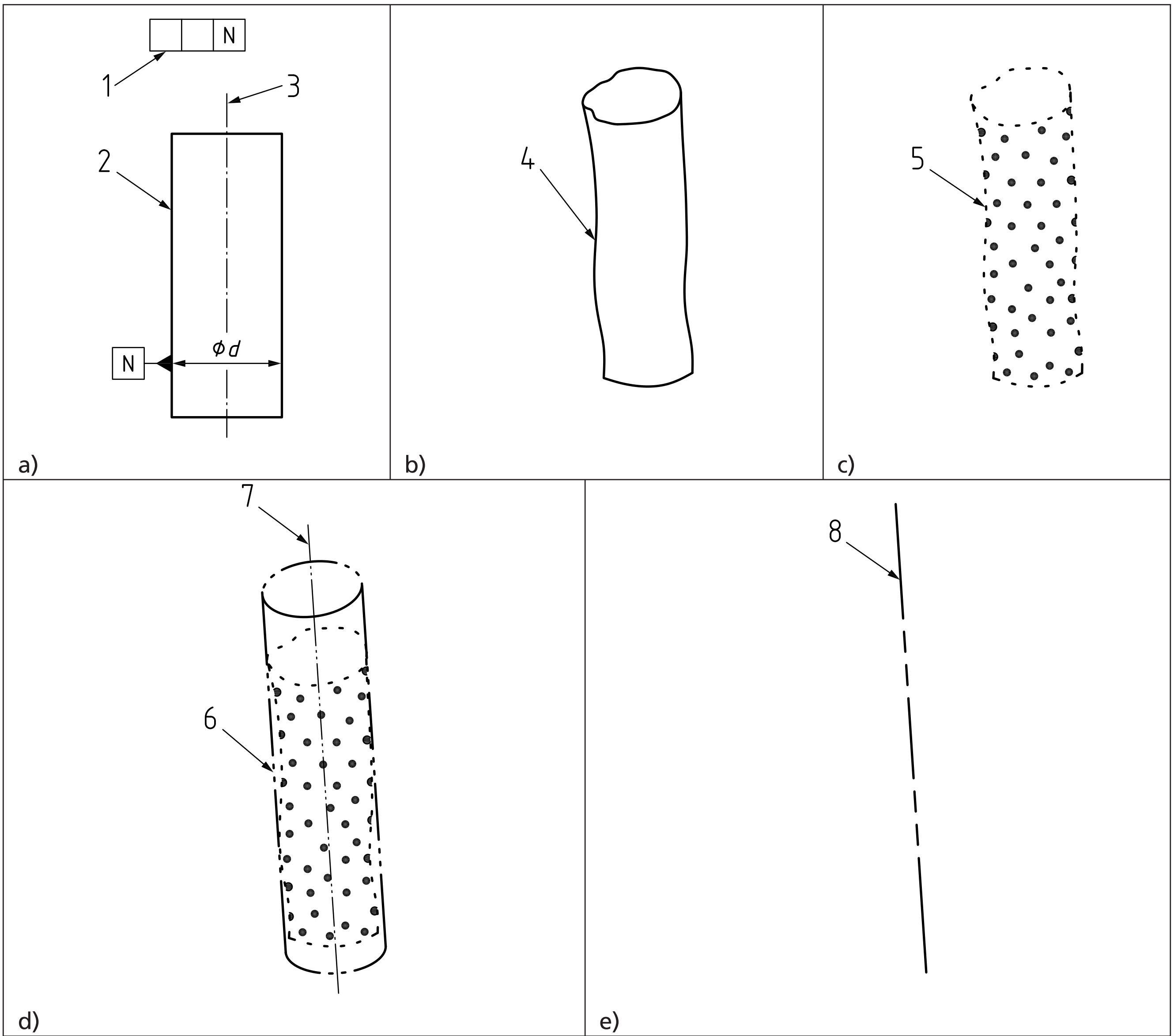
b) An extraction to provide the extracted integral feature [see Figure 19 c)].

c) A filtration.

d) An association to define the associated feature. (In this case, its type is the same as the nominal feature.) The associated feature [see Figure 19 d)] shall be established from the non-ideal surface (in the specification process) or from the extracted feature (in the verification process).

NOTE In Figure 19, the datum is indicated as a single datum derived from a nominal feature, a cylinder, used to orientate or locate a tolerance zone.

Figure 19 **Illustration of features used for establishing a single datum from a cylinder**



Key

1	Tolerance frame to be linked to a toleranced feature	5	Extracted integral feature (optional)
2	Nominal integral feature	6	Associated integral feature
3	Nominal derived feature	7	Derived feature of associated integral feature
4	Real integral feature	8	Single datum (situation feature of the associated surface)

NOTE Figure 19 e), the derived feature, 7, and the situation feature, 8, are the same as each other; this is not always the case.

25.5 Single datums, common datums and datum systems

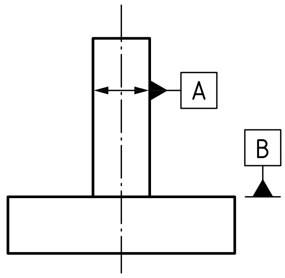
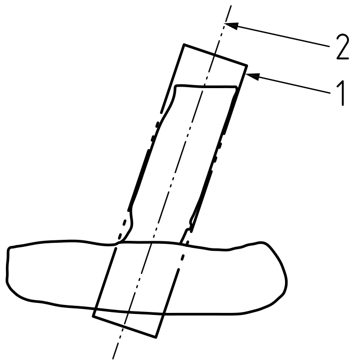
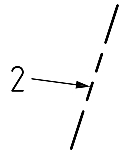
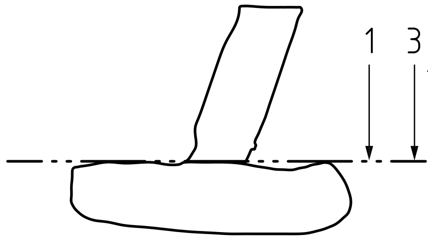
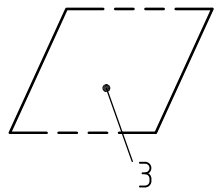
25.5.1 Single datums

A single datum shall consist of one or more situation features based on one single feature or a portion thereof.

NOTE 1 A single datum taken from a cone has two situation features: its axis and a point on that axis.

NOTE 2 A single datum taken from a cylinder or a plane is shown in Table 12.

Table 12 **Interpretation of single datum references**

Indication of datum feature	**Indication of datum in tolerance frame**	**Illustration of the meaning**	**Invariance class and situation feature**	**Datum**
	A		Cylindrical Axis of associated cylinder	
	B		Planar Associated plane	

Key

1 Associated feature (without orientation constraint)

2 Straight line which is the situation feature of the associated cylinder (its axis)

3 Plane which is the situation feature of the associated plane (the associated plane itself)

If a single datum (see Table 12) is used as the only datum in a tolerance frame, or if it is the primary datum in a datum system, the associated feature to the real integral feature (or to the portions of it) used for establishing the datum shall be obtained without external orientation constraints or location constraints.

For a feature of size made up of two opposite parallel planes, the collection surface associated with the surfaces (or to the portions of the surfaces) used for establishing the datum shall be obtained with an internal orientation constraint; the associated surfaces (constituting the collection surface) shall be individually defined with an internal parallelism constraint and a variable intrinsic characteristic constraint.

A secondary datum shall not be specified when it does not constrain more degrees of freedom of the tolerance zone than the primary datum.

A tertiary datum shall not be specified when it does not constrain more degrees of freedom of the tolerance zone than the primary and the secondary datums.

25.6 Common datums

A common datum shall consist of one or more situation features established by taking into account the collection surface.

If the common datum is used as the only datum in a tolerance frame, or if it is the primary datum in a datum system, the collection of associated features used for establishing the datums shall be established without external orientation constraints or location constraints; therefore, the surfaces (constituting the collection surface) shall be associated together, simultaneously.

NOTE The complementary indication [DV] (meaning "distance variable") following the letters indicating a common datum in a tolerance frame means that the linear dimensions between the situation features are variable.

A secondary datum shall not be specified when it does not constrain more degrees of freedom of the tolerance zone than the primary datum.

A tertiary datum shall not be specified when it does not constrain more degrees of freedom of the tolerance zone than the primary and the secondary datums.

25.7 Datum systems

A datum system shall be constituted by an ordered sequence of two or three single or common datums and shall consist of two or three situation features resulting from the collection of the considered surfaces.

The associated features used to establish the datum system shall be derived sequentially, in the order defined by the geometrical specification.

NOTE 1 The relative orientation of the associated surfaces is theoretically exact but their relative location is variable.

This order shall define the orientation constraints for the association operation: the primary datum imposes orientation constraints on the secondary datum and tertiary datum; the secondary datum imposes orientation constraints on the tertiary datum.

NOTE 2 See Table 13, Table 14 and Table 15.

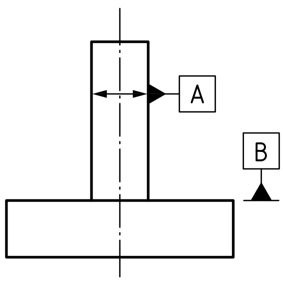
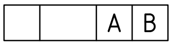
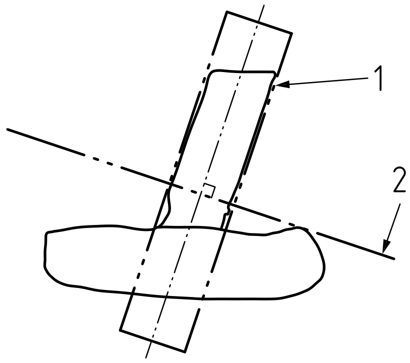
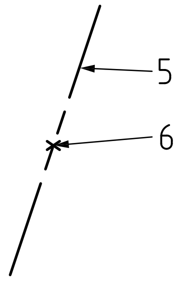
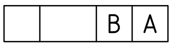
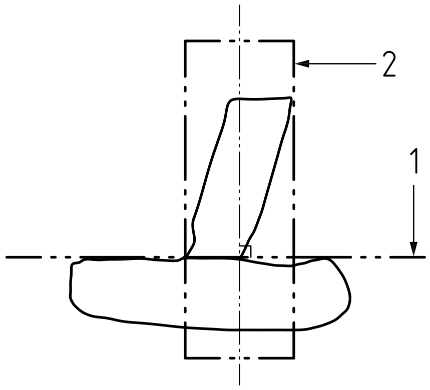
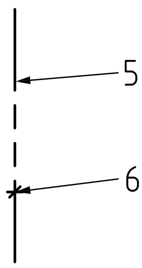
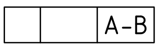
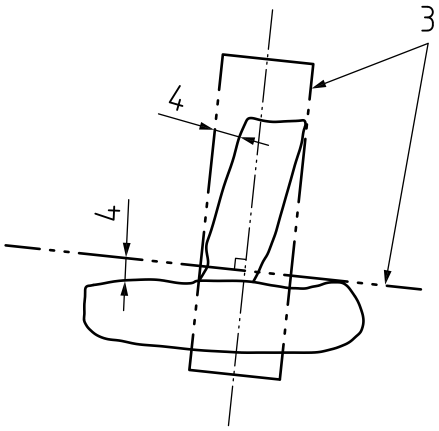
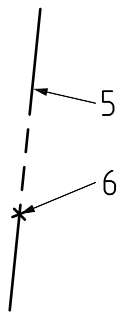
A secondary datum shall be specified when it is necessary to constrain more degrees of freedom of the tolerance zone than are constrained by the primary datum.

A secondary datum shall not be specified when it does not constrain more degrees of freedom of the tolerance zone than are constrained by the primary datum.

A tertiary datum shall be specified when it is necessary to constrain more degrees of freedom of the tolerance zone than are constrained by the primary and the secondary datums.

A tertiary datum shall not be specified when it does not constrain more degrees of freedom of the tolerance zone than are constrained by the primary and the secondary datums.

Table 13 **Common datum or datum system taken from a cylinder and a plane**

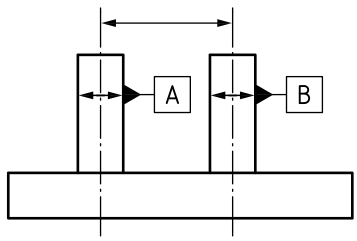
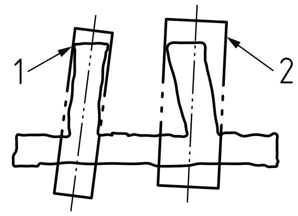
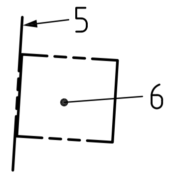
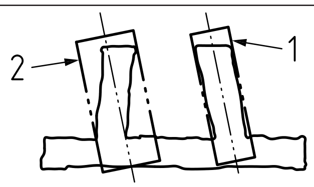
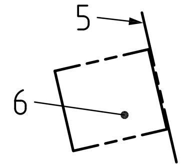
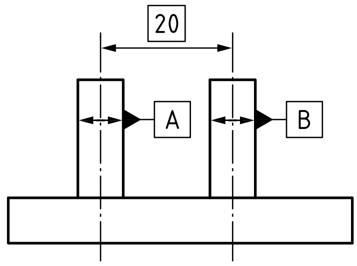
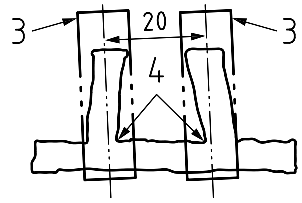
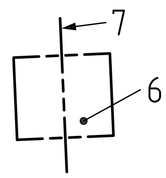
<table>
<tr><th>Indication of datum feature</th><th>Indication of datum in tolerancing frame</th><th>Meaning on workpiece</th><th>Corresponding common datum or datum system</th></tr>
<tr><td rowspan="3"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Key

1 First associated feature without orientation constraint
2 Second associated feature with orientation constraint from the first associated feature
3 Simultaneously associated features with orientation constraint and location constraint
4 Maximum distance balanced between the associated features and datum features
5 Straight line which is the situation feature of the associated cylinder (its axis)
6 Point of intersection between the straight line and the plane

NOTE The orientation and location of datums are different depending on the datum indications in the tolerance frame.

Table 14 **Common datum or datum system taken from two cylinders**

Indication of datum feature	Indication of datum in tolerance frame	Meaning in workpiece	Corresponding datum or datum system
	A B		
	B A		
	A–B		

Key

1 First associated cylinder without constraint

2 Second associated cylinder with parallelism constraint from the first associated feature

3 Simultaneously associated cylinders with parallelism constraint and location constraint

4 Maximum distance balanced between the associated cylinders and datum features

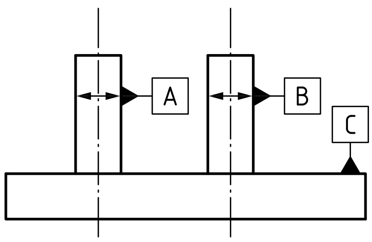
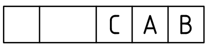
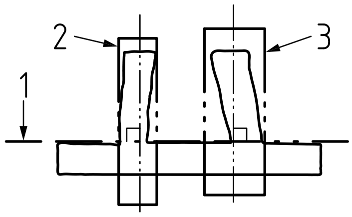
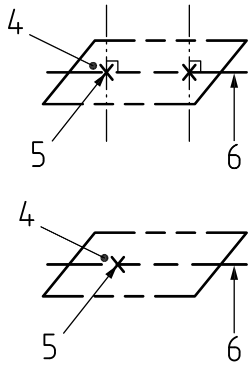
5 Straight line which is the axis of the first associated cylinder

6 Plane including the axes of the two associated cylinders

7 Median plane of the axes of the two simultaneously associated cylinders

NOTE The orientation and location of datums are different depending on the datum indication in the tolerance frame. Not all possibilities for establishing the datums are covered.

Table 15 **Datum system taken from two cylinders and a plane**

Indication of datum feature	**Indication of datums in tolerance frame**	**Meaning on workpiece**	**Corresponding datum or datum system**
			

Key

1 First associated feature without a constraint

2 Second associated feature with a perpendicularity constraint from the first associated feature

3 Third associated feature with a perpendicularity constraint from the first associated feature (and parallelism constraint from the second one)

4 Plane which is the first associated feature

5 Point of intersection between the plane and the axis of the second associated feature

6 Straight line which is the intersection between the associated plane and the plane containing the two axes

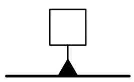
25.8 Indication of datum features

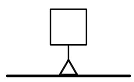
25.8.1 Datum feature indicator

Single features to be used for establishing datum features shall be indicated by a box linked to a filled or open datum triangle by a leader line (see Figure 20).

NOTE There is no difference in meaning between a filled and an open datum triangle.

Figure 20 **Datum feature indicator**





25.8.2 Datum feature letter

Single features used for establishing datum features shall be identified by a capital letter placed in the datum feature indicator.

NOTE A single feature, used to establish a datum, is designated by a datum feature letter (one or more letters not separated by a hyphen).

The letters I, O, Q and X (which can be misinterpreted) shall not be used.

If a drawing has exhausted the alphabet, or if it is useful for the comprehension of the drawing, an unambiguous coding system shall be defined, e.g. by repeating the same letter two times, three times, etc. (e.g. BB, CCC, etc.).

25.9 Datum targets

25.9.1 General

*COMMENTARY ON **25.9.1***

When it is not desirable to use a complete integral feature to establish a datum feature, it is possible to indicate portions of the single feature (areas, lines or points) and their dimensions and locations. These portions are called datum targets. They usually simulate the interface between the considered single feature of the workpiece and one or more contacting ideal features (assembly interface features or fixture features).

A datum target shall be indicated by a datum target indicator. This indicator shall be constructed from a datum target frame, a datum target symbol and a leader line linking the two symbols (directly, or through a reference line).

NOTE It might be necessary to indicate the same datum target on several appropriate views in order to have an unambiguous definition.

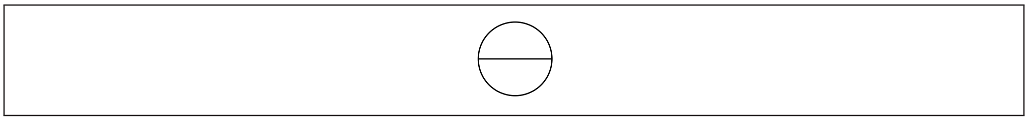
25.9.2 Datum target frame

*COMMENTARY ON **25.9.2***

The datum target frame is a circle, divided into two compartments by a horizontal line (see Figure 21).

The lower compartment shall be reserved for the datum feature letter followed by a digit (from 1 to n), corresponding to the datum target number. The upper compartment shall be reserved for additional information, such as dimensions of the target area.

Figure 21 **Single datum target frame**



25.9.3 Datum target symbol

The datum target symbol shall indicate the type of datum target, point, line, or area, identifying a datum target point, a datum target line or a datum target area, respectively:

a) a cross (see Figure 22);

b) a long-dashed double-dotted narrow line (type 05.1 of BS ISO 128-24:1999), which, when this line is not closed, is terminated by two crosses (see Figure 23 and Figure 24). This line might be straight, circular or a line of any shape;

c) a hatched area surrounded by a long-dashed double-dotted narrow line (type 05.1 of BS ISO 128-24:1999) (see Figure 25).

Figure 22 **Datum target symbol**

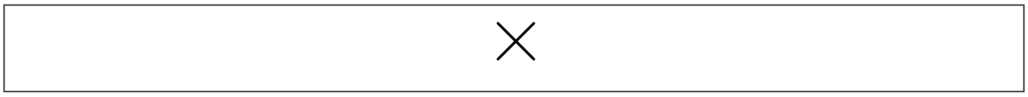


Figure 23 **Non-closed datum target line**

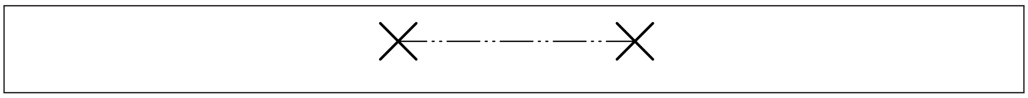


Figure 24 **Closed datum target line**

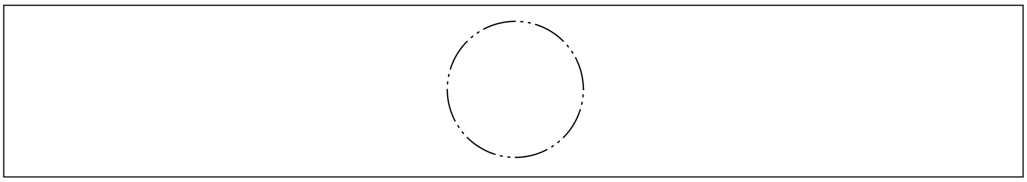
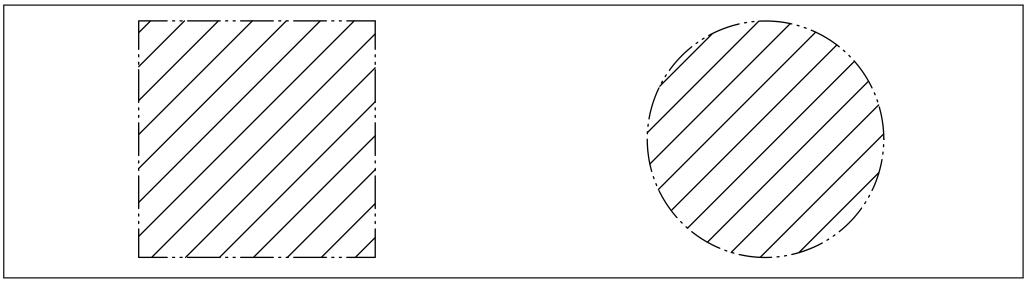


Figure 25 **Datum target area**



25.9.4 Leader line

The datum target frame shall be connected directly, or through a reference line, to the datum target symbol by a leader line terminated with or without an arrow or a dot (see Figures 26, 27 and 28).

When the datum target point or the datum target line is not hidden, the leader line shall be continuous and shall be terminated with or without an arrow (see Figure 26 and Figure 27).

When the datum target area is shown as an area in the relevant view and is not hidden, the leader line shall be continuous and shall be terminated with or without a dot (see Figure 28).

When the considered surface is hidden, the leader line shall be dashed and terminated by an open circle for a datum target area (see Figure 28) or without terminator in the other cases.

NOTE The orientation of the leader line connecting the frame with the datum target symbol is unimportant.

A datum target shall be indicated on a view where it is not hidden, if possible.

Figure 26 **Indicator for single datum target point**

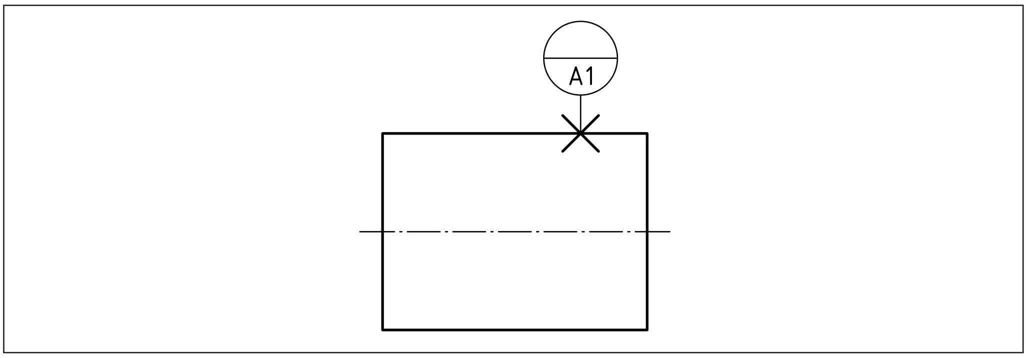


Figure 27 **Indicator for single datum target line**

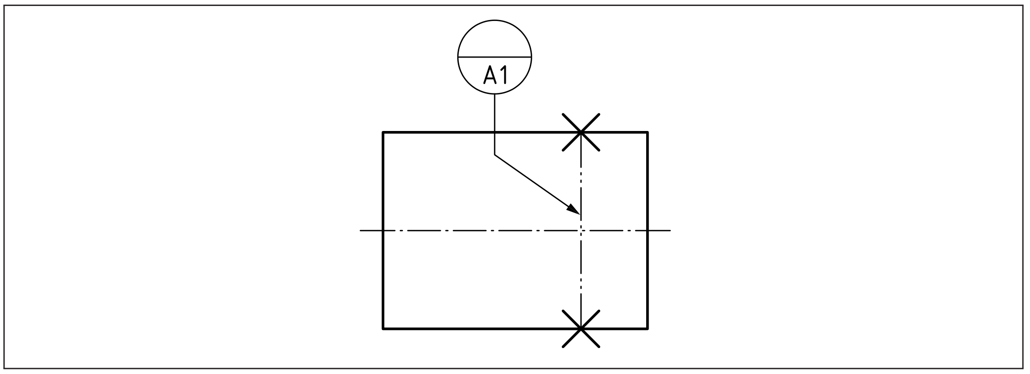
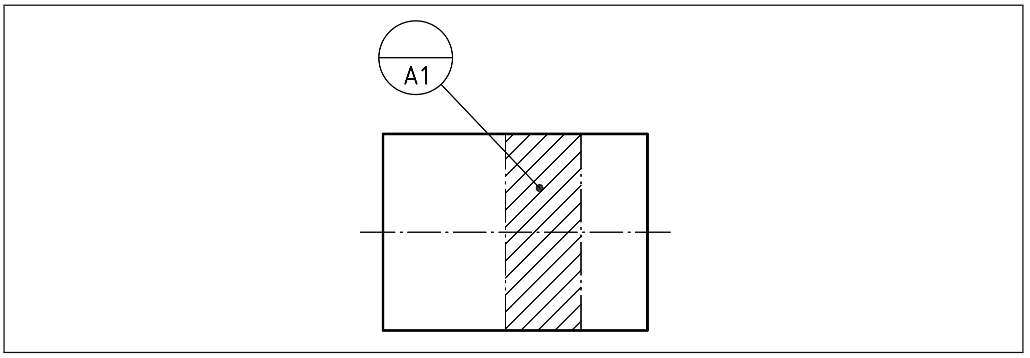


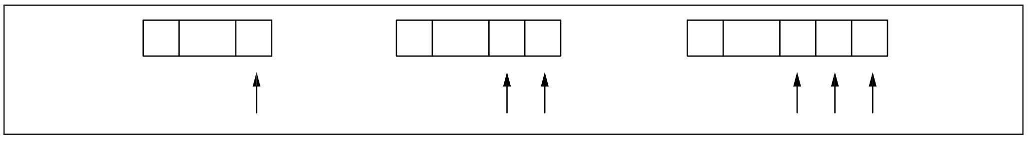
Figure 28 **Indicator for single datum target surface**



25.10 Specification of datums and datum systems

The datum (or datum system) shall be specified in the third (and if necessary fourth and fifth) compartment of the tolerance frame (see Figure 29) as described in BS EN ISO 1101:2005, **6.1**.

Figure 29 **Location of datum letter symbol(s) in the tolerance frame**



26 Rules for datums and datum systems

26.1 Indication and meaning of rules

NOTE 1 Humans interact with technical product documentation in two ways.

a) Designers encode the datum requirements into graphical language.

b) Other users decode the datum requirements from the graphical language.

NOTE 2 See BS EN ISO 5459 for more information on all rules and more detail on individual rules.

To encode the location constraints or orientation constraints, or both, for the tolerance zone from features on the workpiece, the following steps shall be performed.

a) Indicate and identify all datum features used to establish the datum features with datum indicators (rule 1, **26.2**) and, if necessary, define datum target(s) (rules 3 and 4, **26.3** and **26.4**).

b) Consider how the datums are established from the datum features by defining the manner of association, relevant constraints and types of features (rules 2, 5, 6, 7, 8, 9 and 10).

If more than one associated feature is used to establish a datum or datum system, the associations shall be realized sequentially or simultaneously (rules 6 and 7, **26.5** and **26.6**).

NOTE 3 For the datum or each datum comprising the datum system, see the applicable rule as follows.

- *If the type of associated feature is not the same as the datum feature (contacting feature; rule 55).*
- *If the size of a feature of size is considered fixed or variable (rule 2).*
- *If the constraint given by a datum needs to be reduced (rules 8 and 9).*
- *If a geometrical modifier (Ⓜ, Ⓛ or Ⓟ) is required for a datum (rule 10).*

To decode the meaning of a datum or datum system, the following steps shall be performed.

- Read the tolerance frame to determine whether datums are used. If the tolerance frame contains more than two compartments, then at least one datum is used (rule 6).
- Read all datum letter symbols corresponding to single datums or common datum components (rule 7).
- Look for the datum feature corresponding to each datum letter symbol (rule 1).
- See if the datum feature is the complete integral feature (rule 3). If not, it is necessary to read the datum target(s) and its (their) definition(s) (consider TEDs; rule 4).
- Consider how the associations shall be processed to establish the datum (rules 2, 5, 6, 7, 8, 9 and 10).

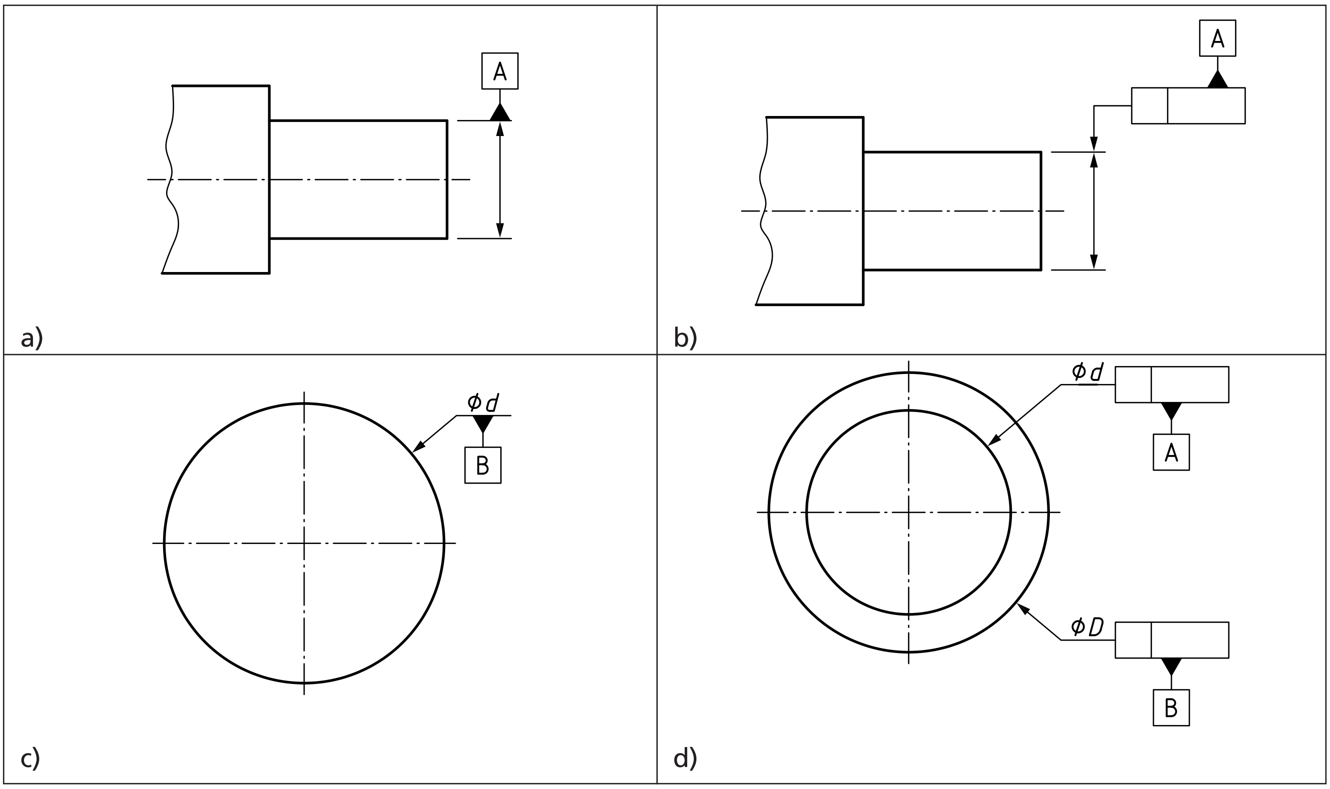
26.2 Rule 1 – Datum features (established from a single feature)

Where the single feature used for establishing a datum is a feature of size, the surface shall be designated by a datum feature indicator placed:

- as an extension of a dimension line [see Figure 30 a)];
- on a tolerance frame pointing to an extension of a dimension line for the surface [see Figure 30 b)];
- on the reference line of a dimension [see Figure 30 c)];
- on a tolerance frame linked to a reference line with a dimension and pointing to the surface [see Figure 30 d)].

If the single feature is a helical surface or a complex surface (e.g. screw, cylindrical gear), it shall be considered a cylindrical surface. If there is no complimentary indicator, the datum shall be established from a pitch cylinder having the pitch diameter of the single feature and the modifier [PD]Ⓟ can be omitted. When the datum is established from a major cylinder (having the major diameter of the single feature) or a minor cylinder (having the minor diameter of the single feature), the symbol [MD] or [LD], respectively, shall be placed in the proximity of the datum indicator.

Figure 30 **Attachment of a datum indicator for a single feature considered a feature of size**



Where the single feature used for establishing a datum is not a feature of size, the surface shall be designated by a datum indicator placed on one of the following.

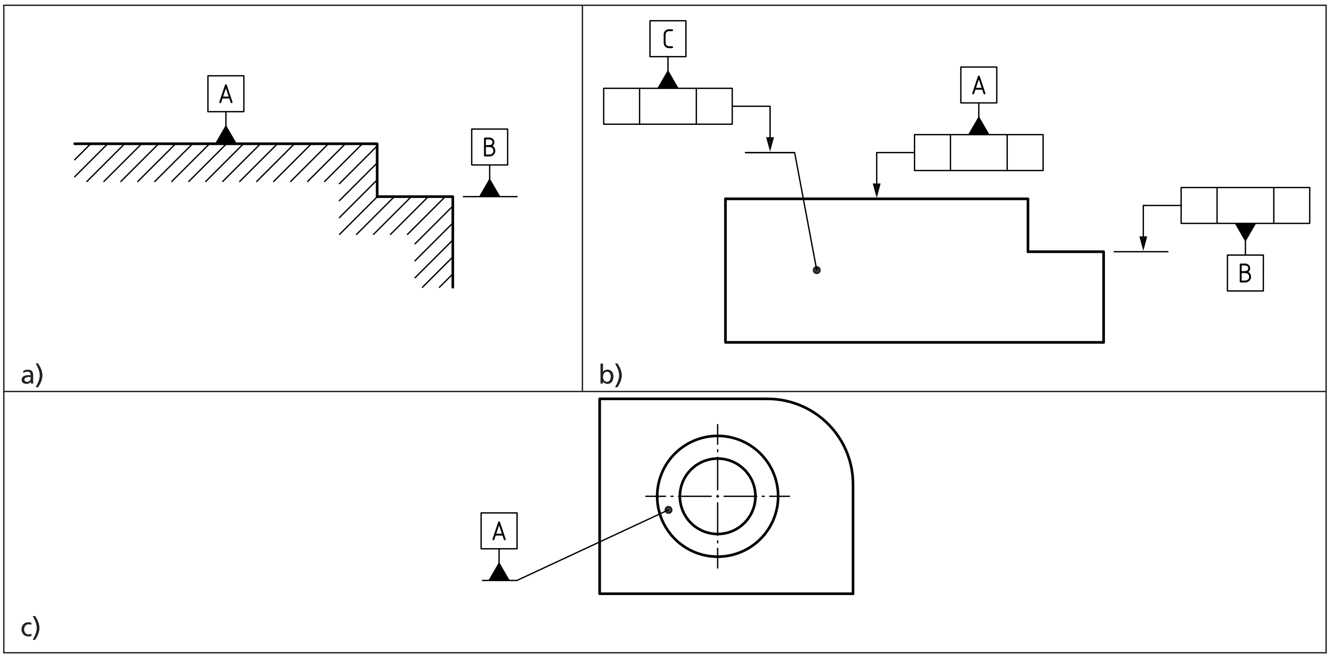
a) The outline of the surface [see Figure 31 a), datum feature letter A].

b) An extension line of the surface [see Figure 31 a), datum feature letter B].

c) A tolerance frame pointing to the outline or extension line of the surface or on a reference line [see Figure 31 b)].

d) A reference line with a leader line that does not relate to a dimension, attached to the surface, terminating in a filled circle. A datum indicator on a view where the surface is not hidden (see Figure 31) shall be indicated.

Figure 31 **Attachment of a datum indicator for a single feature not considered a feature of size**



NOTE 1 The meaning of a datum indicator attached to a tolerance frame for a single feature that is a feature of size is identical to that of a datum indicator identifying a feature of size placed in any other permitted manner (see Figure 31).

NOTE 2 Rule 2 has not been included. See BS EN ISO 5459.

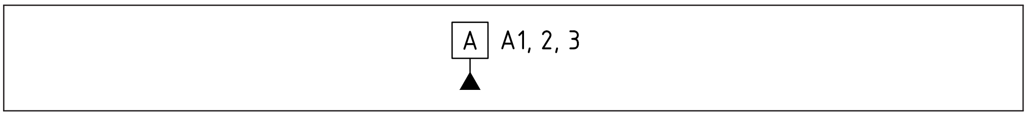
26.3 Rule 3 – Datum features established from a complete feature

If a datum is established from a complete integral feature, it shall be indicated with a datum indicator only.

26.4 Rule 4 – Datum features established from one or more datum targets

If a datum is established from one or more datum targets belonging to only one surface, then the datum feature letter identifying the surface shall be repeated close to the datum indicator, followed by the list of numbers (separated by commas) identifying the targets (see Figure 32). Each individual datum target shall be identified by a datum target indicator, indicating the datum feature letter, the number of the datum target and, if applicable, the dimensions of the datum target.

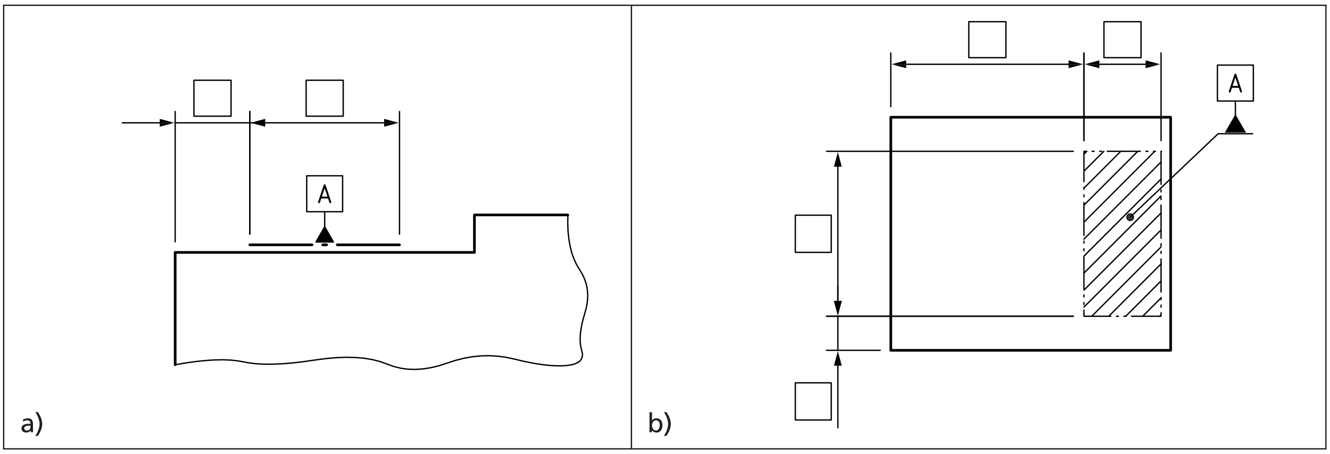
Figure 32 **Indication of datums established from datum targets**



NOTE 1 If there is only one datum target, the drawing indication could be simplified by placing the datum indicator in accordance with rule 1 for a feature of size:

- *on a long-dashed dotted wide line (type 04.2 of ISO 128-24:1999) defining the portion of the considered surface [see Figure 33 a)];*
- *on the reference line of a leader line pointing to a hatched area surrounded by a long-dashed double-dotted narrow line (type 05.1 of ISO 128-24:1999) [see Figure 33 b)].*

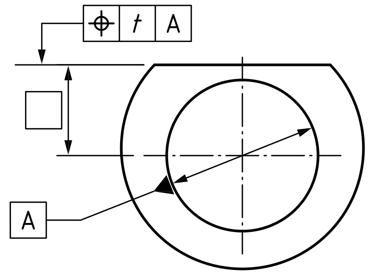
Figure 33 **Simplification of drawing indication when there is only one datum target area**



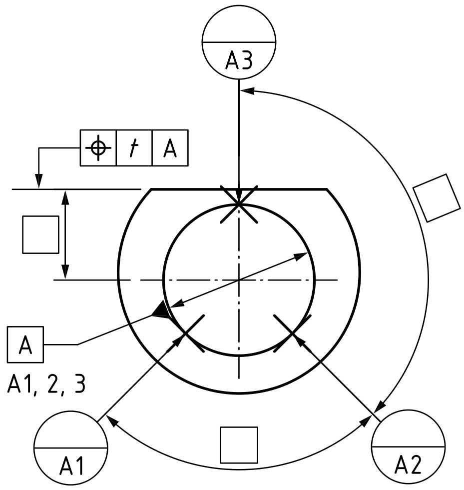
The relative location of datum targets on one single feature shall be defined by angular and/or linear TED(s) when it shall be considered fixed.

When a set of datum targets is used to simulate a feature of size, the number and the location of the datum targets shall be adequate to simulate its size and the relative location shall be defined by a linear or angular TED [see Figure 34 b)]. Where datum targets are located from another feature, linear TED are required [see Figure 34 c)].

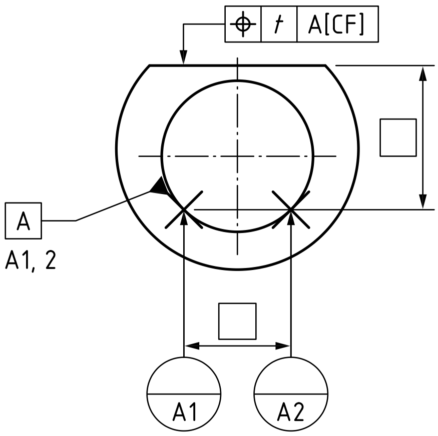
Figure 34 **Examples of single datums established from a complete cylinder, a portion of a cylinder or with a contacting feature**



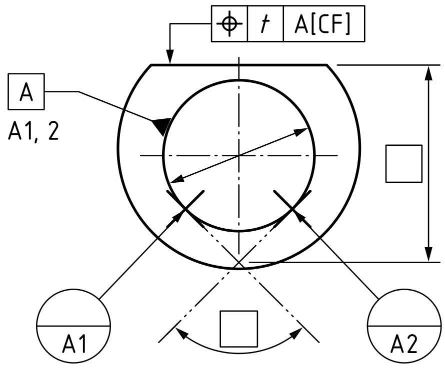
a) The associated feature used to establish the datum from the complete integral feature is a cylinder and the datum shall be its axis.



b) The angular locations between the datum target lines A1, A2 and A3 shall be indicated by TEDs and shall be considered as fixed. The associated feature used to establish the datum from 3 datum target lines is a cylinder and the datum shall be its axis. (To fully define datum target lines A1, A2 and A3 more than one drawing view shall be used.)



c) The distance between datum targets A1 and A2 shall be indicated by a TED and shall be fixed. The associated feature used to establish the datum shall not be a cylinder and the datum shall not be its axis. The datum shall consis of two planes: one plane through two datum target lines and a second perpendicular median plane.



d) The datum targets A1 and A2 shall be defined by the interface between the cylinder A and a contacting feature. The distance between datum targets A1 and A2 is variable and shall depend on the actual diameter of the cylinder and the contacting feature defined in this case by a "V" block of angle α. The associated feature used to establish the datum shall be the "V" block, not a cylinder.

The beginning and the end of the location of a datum target line shall be considered theoretically exact locations and defined by TEDs.

The extent of a datum target area shall be considered theoretically exact. The dimensions of the area shall be indicated:

- either in the upper compartment of the datum target indicator when the area is circular, square (see Figure 35), or rectangular, or placed outside and connected to the appropriate compartment by either a leader line or by a leader line and a reference line if the space within the compartment is limited [see Figure 36 a)]; or

- directly on the drawing by TEDs when the area is neither square nor circular [see Figure 36 b)].

NOTE 2 In the case of a point or a line, it might be necessary to indicate the datum target on several views in order to have an unambiguous definition.

Figure 35 **Indication of dimension of a circular/square area**

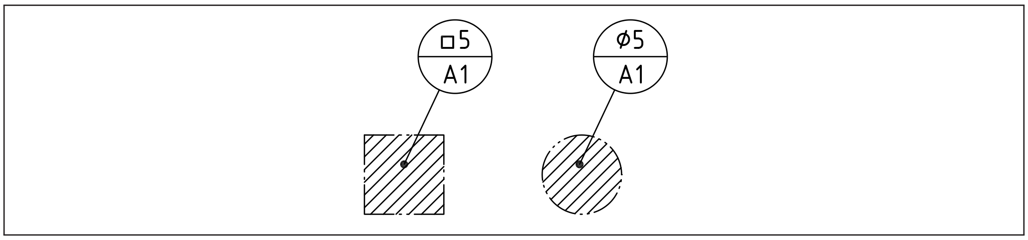
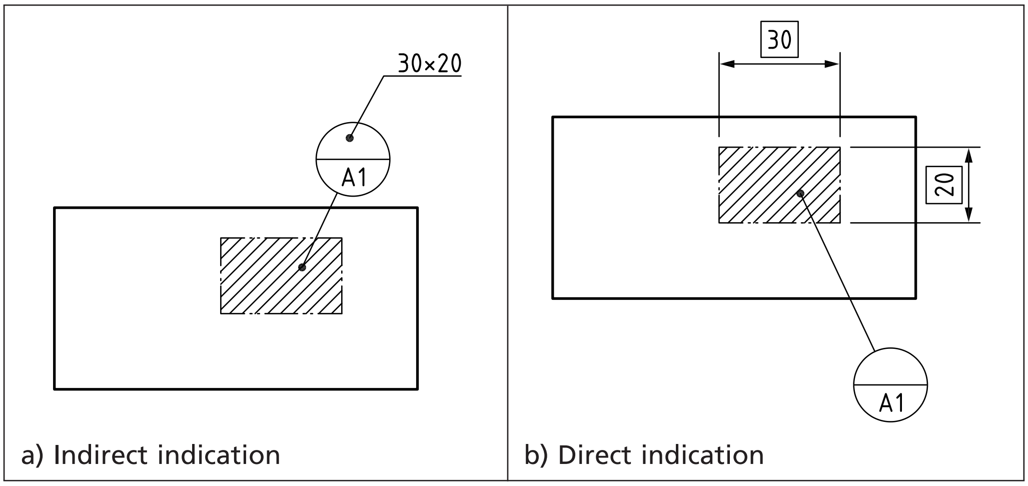


Figure 36 **Indication of dimensions of a rectangular area**



NOTE 3 Rule 5 has not been included. See BS EN ISO 5459.

26.5 Rule 6 – Tolerance frame layout with a datum or a datum system

If the tolerance frame has only three compartments, only a single datum or a common datum used as a primary datum shall be specified [see Figures 37 a) and 37 b)].

If the tolerance zone is oriented or located from only one datum established from a single feature, then the tolerance frame shall only have three compartments and the single datum shall be indicated in the third compartment [see Figure 37 a)].

If the tolerance zone is oriented or located from only one datum established simultaneously from more than one single feature, then the tolerance frame shall only have three compartments and the common datum shall be indicated in the third compartment [see Figure 37 b)].

If the tolerance zone is oriented or located from more than one datum established in a specific order, then the tolerance frame shall have more than three compartments and each compartment after the second compartment shall indicate a single or common datum [see Figures 37 c) to 38 e)]. The specified order shall define the orientation constraints between the primary, secondary and tertiary datums (single or common). The value of the constraints shall be specified by TEDs.

NOTE 1 TED values of 0°, 90°, 180° and 270° are implicit and not indicated.

NOTE 2 In a datum system, the primary datum is identified in the third compartment of the tolerance frame; the secondary datum is identified in the fourth compartment of the tolerance frame; the tertiary datum is identified in the fifth compartment of the tolerance frame.

Figure 37 **Examples of indication of datums in the tolerance frame**

| | | A | a) Single datum used alone	| | | R–S | b) Common datums used alone
| | | B | A | c) Two single datums used in a system	| | | G | P | S | d) Three single datums used in a system
| | | A | U–V | e) A single datum and a common datum used in a system	

26.6 Rule 7 – Indication of a single or common datum in a compartment of a tolerance frame

When the datum is a single datum, it shall be indicated by one datum letter in a compartment of the tolerance frame [see Figures 37 a), 37 c) and 37 d)].

When the datum is a common datum, it shall be indicated by a sequence of datum letters separated by hyphens in a compartment of the tolerance frame [see Figures 37 b) and 37 e)].

The datum letters given in the tolerance frame shall be the same as the letters given in the datum indicators.

In the case of a common datum, the following points shall apply.

a) The associated features that establish a common datum are by default constrained in location and orientation to each other. If the modifier [DV] is placed in the tolerance frame after the letter(s) identifying a common datum, then the linear distance between the members of the collection of features that make up this common datum shall be considered variable.

b) The orientation and location constraints correspond to the intrinsic characteristics introduced by the collection of features and are specified by TEDs. The values of 0 mm, 0°, 90°, 180° and 270°, and equally divided linear or angular dimensions might be implicit TEDs and not indicated.

c) There are as many datum feature letters in the tolerance frame as single features used for establishing the common datum, unless a simplified indication is used.

d) The sequence of the letters identifying the common datum has no significance.

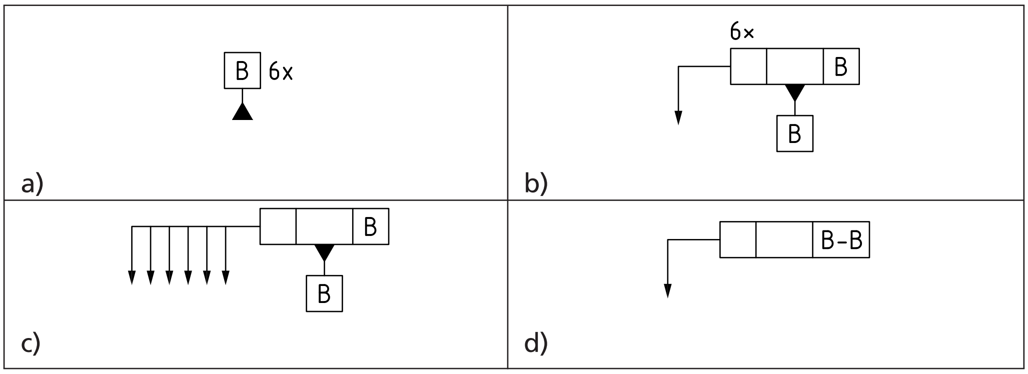
e) It is possible to simplify the drawing indication by:

- using only one datum indicator;
- using only one doubled letter separated by a hyphen in the tolerance frame [(see Figure 38 d)]; and
- adding the complementary indication “n ×” giving the number, n, of surfaces in the collection on the right side of a datum indicator attached to one of the surfaces [see Figure 38 a)].

NOTE 1 When the datum indicator points to the tolerance frame, the indication “n ×” is not written on the right side of a datum indicator but above the tolerance frame [see Figure 38 b)], or, when the datum indicator points to the tolerance frame, by using leader lines indicating each surface included in the common datum [see Figure 38 c)].

NOTE 2 Rules 8 and 9 have not been included. See BS EN ISO 5459.

Figure 38 **Examples of complementary indication**



26.7 Rule 10 – Application of geometrical modifiers in a tolerance frame

If the modifier Ⓜ, Ⓛ or Ⓟ is placed in the tolerance frame after the letter, then the default meaning changes; the modifiers [CZ] and Ⓕ shall not be written after a datum in the tolerance frame.

If one of the modifiers Ⓜ or Ⓛ is placed in the tolerance frame after the letter indicating a datum, the datum shall be established in accordance with BS EN ISO 2692.

When the modifier Ⓟ is placed in the tolerance frame after the letter indicating a datum established from a feature of size, then the datum feature shall be established by fitting an associated feature of the projected length to the extension of the real feature, and not the real integral feature itself.

When using the modifier Ⓟ, the extension of the feature shall be indicated, directly on the drawing (see Figure 39) or after the modifier Ⓟ in the tolerance frame. The dimension(s) of this extension shall be seen as a TED.

NOTE The modifier Ⓟ can be applied to a secondary or tertiary datum. In Figure 39 and Figure 40, the effect of this modifier is shown when the datum is a secondary datum in datum system. The modifier has no effect when it is applied to a primary datum, and the same association criteria are used to define the projected datum feature and to determine the datum.

Figure 39 **Example of application of modifier Ⓟ on the secondary datum**

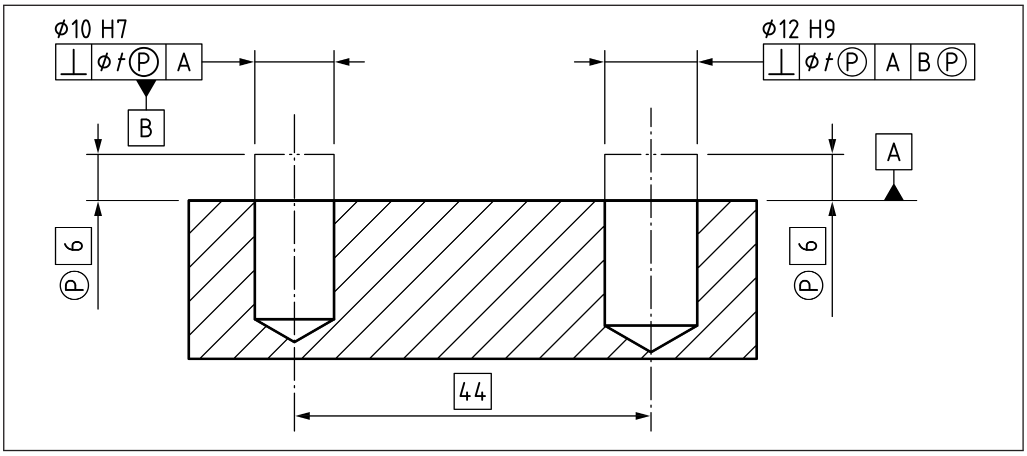
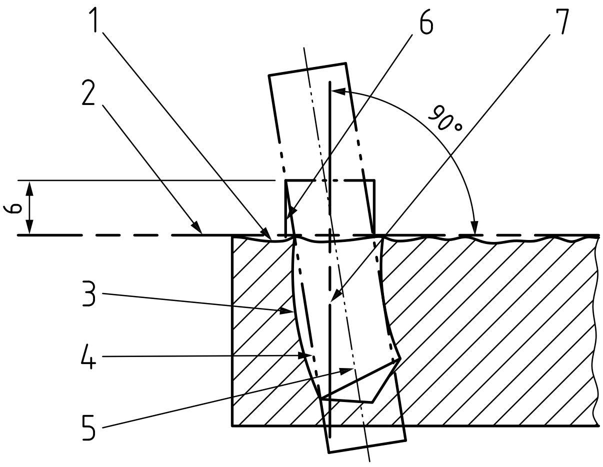


Figure 40 **Meaning of the specification given in Figure 39**



Key

1	Real integral feature of the planar surface	5	Derived feature of 4
2	Datum A: an associated integral feature to 1	6	Associated integral feature to the portion of 4, with the constraint perpendicular to 2
3	Real integral feature of the cylindrical surface		
4	Associated integral feature to 3	7	Associated integral feature to the portion of 4, with the constraint perpendicular to 2

27 Geometrical tolerances

27.1 General

Geometrical tolerancing shall conform to the following standards, as appropriate.

BS EN ISO 1101 *Technical drawings – Geometrical tolerancing – Tolerancing of form, orientation, location and run-out – Generalities, definitions, symbols, indications on drawings*

BS EN ISO 2692 *Geometrical product specifications (GPS) – Geometrical tolerancing – Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)*

BS EN ISO 5458	*Geometrical Product Specifications (GPS) – Geometrical tolerancing – Positional tolerancing*
BS EN ISO 5459	*Technical drawings – Geometrical tolerancing – Datums and datum-systems for geometrical tolerances*
BS EN ISO 7083	*Technical drawings – Symbols for geometrical tolerancing – Proportions and dimensions*
BS ISO 10578	*Technical drawings – Tolerancing of orientation and location – Projected tolerance zone*
BS EN ISO 12180-1	*GPS – Cylindricity – Part 1: Vocabulary and parameters of cylindrical form*
BS EN ISO 12180-2	*GPS – Cylindricity – Part 2: Specification operators*
BS EN ISO 12181-1	*GPS – Roundness – Part 1: Vocabulary and parameters of roundness*
BS EN ISO 12181-2	*GPS – Roundness – Part 2: Specification operators*
BS EN ISO 12780-1	*GPS – Straightness – Part 1: Vocabulary and parameters of straightness*
BS EN ISO 12780-2	*GPS – Straightness – Part 2: Specification operators*
BS EN ISO 12781-1	*GPS – Flatness – Part 1: Vocabulary and parameters of flatness*
BS EN ISO 12781-2	*GPS – Flatness – Part 2: Specification operators*

27.2 Basic concepts

Geometrical tolerances shall be specified in accordance with functional requirements.

NOTE 1 Manufacturing and inspection requirements can also influence geometrical tolerancing.

NOTE 2 Indicating geometrical tolerances on a drawing does not necessarily imply the use of any particular method of production, measurement or gauging.

A geometrical tolerance applied to a feature defines the tolerance zone within which that feature shall be contained.

NOTE 3 A feature is a specific portion of the workpiece, such as a point, a line or a surface; these features can be integral features (e.g. the external surface of a cylinder) or derived (e.g. a median line or median surface). See BS EN ISO 14660-1.

According to the characteristic to be toleranced and the manner in which it is dimensioned, the tolerance zone shall be one of the following:

- the space within a circle;
- the space between two concentric circles;
- the space between two equidistant lines or two parallel straight lines;
- the space within a cylinder;
- the space between two coaxial cylinders;
- the space between two equidistant surfaces or two parallel planes;
- the space within a sphere.

Unless a more restrictive indication is required, for example by an explanatory note, the toleranced feature shall be of any form or orientation within this tolerance zone.

The tolerance shall apply to the whole extent of the considered feature unless otherwise specified as in **27.9** and **27.10**.

NOTE 4 Geometrical tolerances which are assigned to features related to a datum do not limit the form deviations of the datum feature itself. It might be necessary to specify tolerances of form for the datum feature(s).

27.3 Symbols

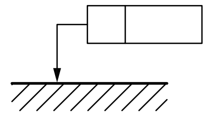
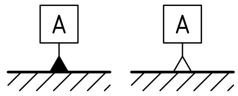
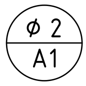
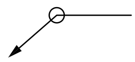
Symbols for geometrical characteristics shall be as indicated in Table 16 and Table 17 and as indicated in BS EN ISO 1101.

NOTE Examples illustrating the application of each of the tolerance characteristics may be found in Annex C.

Table 16 **Symbols for geometrical characteristics**

Tolerances	Characteristics	Symbol	Datum needed
Form	Straightness	—	no
	Flatness	⏥	no
	Roundness	○	no
	Cylindricity	⌭	no
	Profile any line	⌒	no
	Profile any surface	⌓	no
Orientation	Parallelism	//	yes
	Perpendicularity	⊥	yes
	Angularity	∠	yes
	Profile any line	⌒	yes
	Profile any surface	⌓	yes
Location	Position	⌖	yes or no
	Concentricity (for centre points)	◎	yes
	Coaxiality (for axes)	◎	yes
	Symmetry	⌯	yes
	Profile any line	⌒	yes
	Profile any surface	⌓	yes
Run-out	Circular run-out	↗	yes
	Total run-out	⌰	yes

Table 17 **Additional symbols**

Description	Symbol
Toleranced feature indication	
Datum feature indication	
Datum target indication	
Theoretically exact dimensions	[50]
Projected tolerance zone	Ⓟ
Maximum material requirement	Ⓜ
Least material requirement	Ⓛ
Free state condition (non-rigid parts)	Ⓕ
All around (profile)	
Envelope requirement	Ⓔ
Common zone	CZ
Minor diameter	LD
Major diameter	MD
Pitch diameter	PD
Line element	LE
Not convex	NC
Any cross-section	ACS

NOTE Further symbols and modifiers are standardized in BS EN ISO 1101 and other standards.

27.4 Tolerance frame

According to BS EN ISO 1101, the requirements shall be shown in a rectangular frame which is divided into two or more compartments. These compartments shall contain, from left to right, in the following order.

- The symbol for the geometrical characteristic; the tolerance value in the unit used for linear dimensions.
- This value shall be preceded by the symbol "Ø" if the tolerance zone is circular or cylindrical or by "SØ" if the tolerance zone is spherical.
- If applicable, the letter or letters identifying the datum or common datum or datum system (see examples of Figure 38).

When a tolerance applies to more than one feature this shall be indicated above the tolerance frame by the number of features followed by the symbol "×" [see Figure 41 a) and 41 b)].

If required, indications qualifying the form of the feature within the tolerance zone shall be written near the tolerance frame (see example of Figure 42).

NOTE If it is necessary to specify more than one geometrical characteristic for a feature, the requirements may be given in tolerance frames one under the other for convenience (see example of Figure 43).

Figure 41 **Tolerance applying to more than one feature**

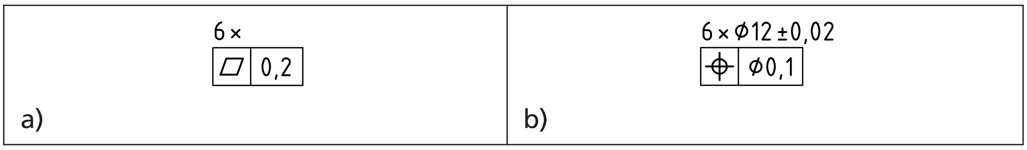


Figure 42 **Indications qualifying the form of the feature within the tolerance zone**

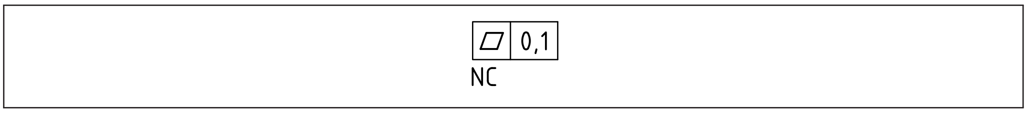
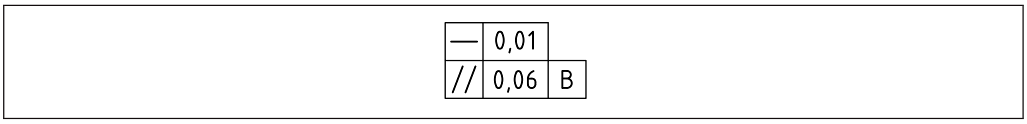


Figure 43 **Requirements given in tolerance frames one under the other**



27.5 Toleranced features

As specified by the requirements of BS EN ISO 1101, the tolerance frame shall be connected to the toleranced feature by a leader line starting from either side of the frame and terminating with an arrowhead in one of the following ways.

- On the outline of the feature or an extension of the outline (but clearly separated from the dimension line) when the tolerance refers to the line or surface itself [see Figure 44 a) and 44 b)].

NOTE 1 The arrowhead could be placed on a reference line using a leader line to point to the surface (see example of Figure 44 c).

- As an extension of the dimension line when the tolerance refers to the median line or median surface or a point defined by the feature so dimensioned [see Figure 45 a) to 45 c)].

If needed, an indication specifying the form of the feature (line instead of a surface) shall be written near the tolerance frame.

NOTE 2 When the toleranced feature is a line, a further indication might be needed to control the orientation.

Figure 44 **Arrowhead terminating on the outline of the feature or as an extension**

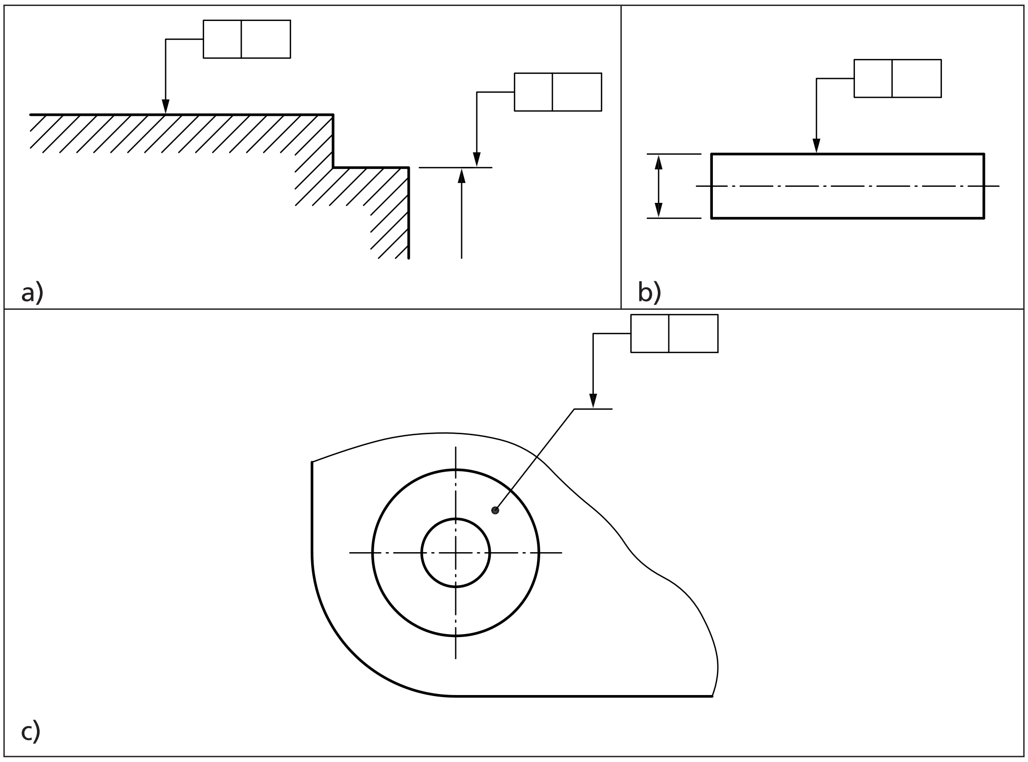
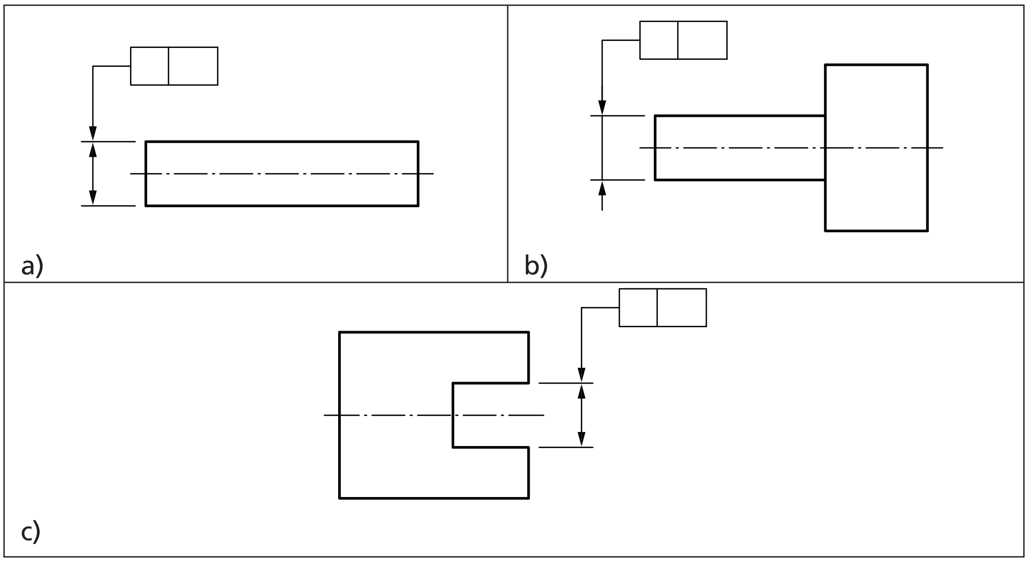


Figure 45 **Arrowhead terminating as an extension of the dimension line**

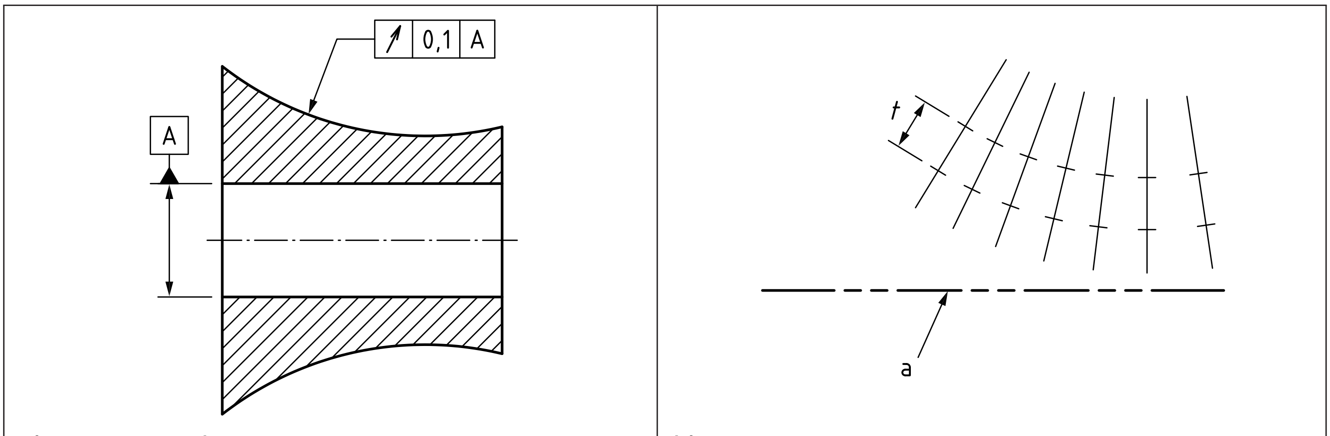


27.6 Tolerance zones

The width of the tolerance zone shall apply normal to the specified geometry [see Figure 46 a) and 46 b) unless otherwise indicated [see Figure 47 a) and 47 b).

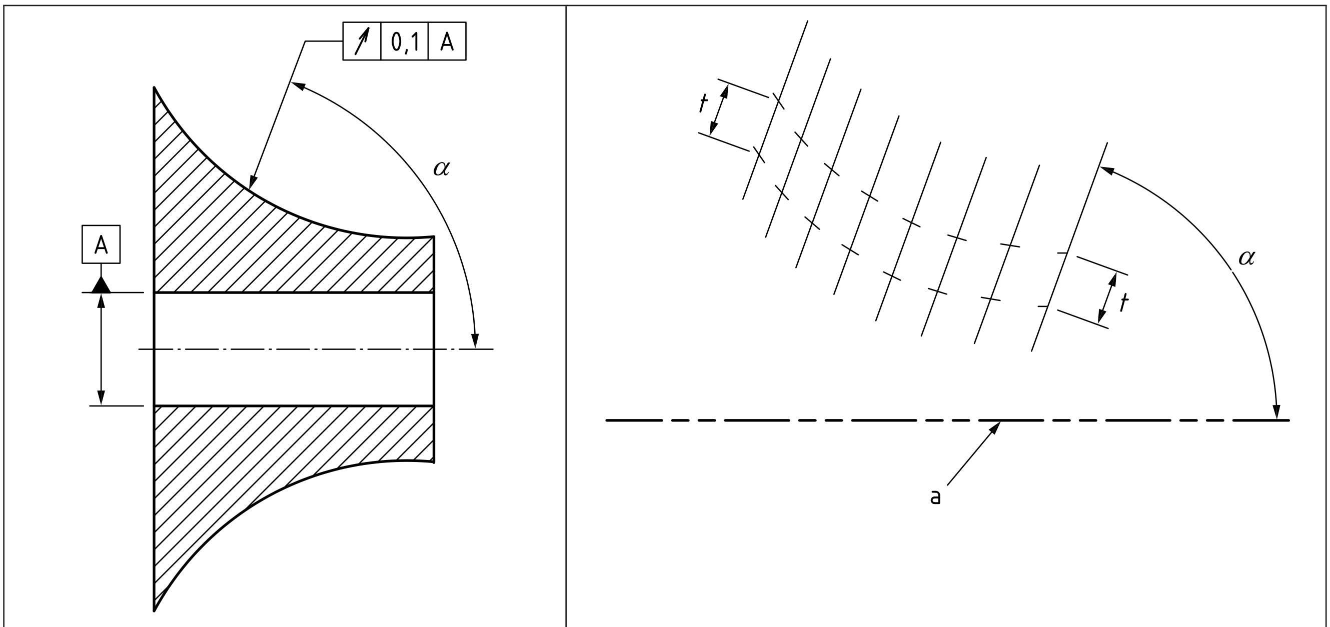
NOTE 1 The orientation alone of the leader line does not influence the definition of the tolerance.

Figure 46 **Width of tolerance zone applying to the specified geometry**



a) Drawing indication b) Interpretation

Figure 47 **With of tolerance zone, otherwise indicated**



a) Drawing indication b) Interpretation

The angle α shown in Figure 47 a) shall be indicated, even if it is equal to 90°.

In the case of roundness, the width of the tolerance zone shall always apply in a plane perpendicular to the nominal axis.

In the case of a centre point or median line or median surface toleranced in one direction:

- the orientation of the width of a positional tolerance zone shall be based on the pattern of the theoretically exact dimensions (TED) and is at 0° or 90° as indicated by the direction of the arrowhead of the leader line unless otherwise indicated (see Figure 48);
- the orientation of the width of an orientation tolerance zone shall be at 0° or 90° relative to the datum as indicated by the direction of the arrowhead of the leader line unless otherwise indicated (see Figures 49 and 50);
- when two tolerances are stated, they shall be perpendicular to each other unless otherwise specified (see Figures 49 and 50).

Figure 48 **Orientation of the width of a positional tolerance zone**

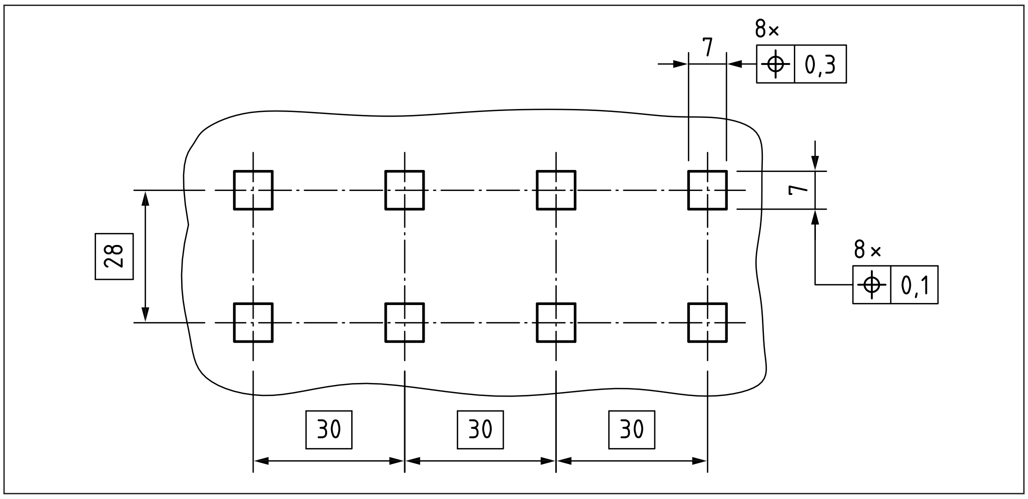


Figure 49 **Orientation of the width of an orientation tolerance zone**

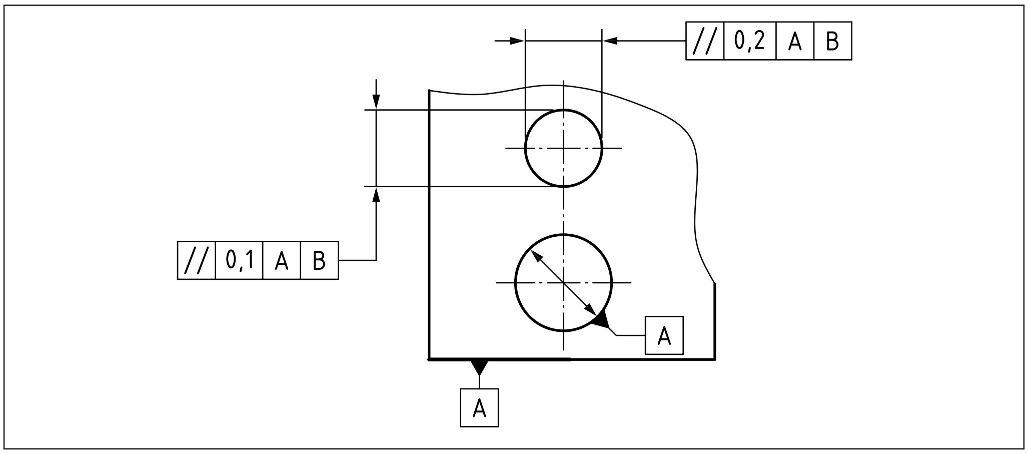
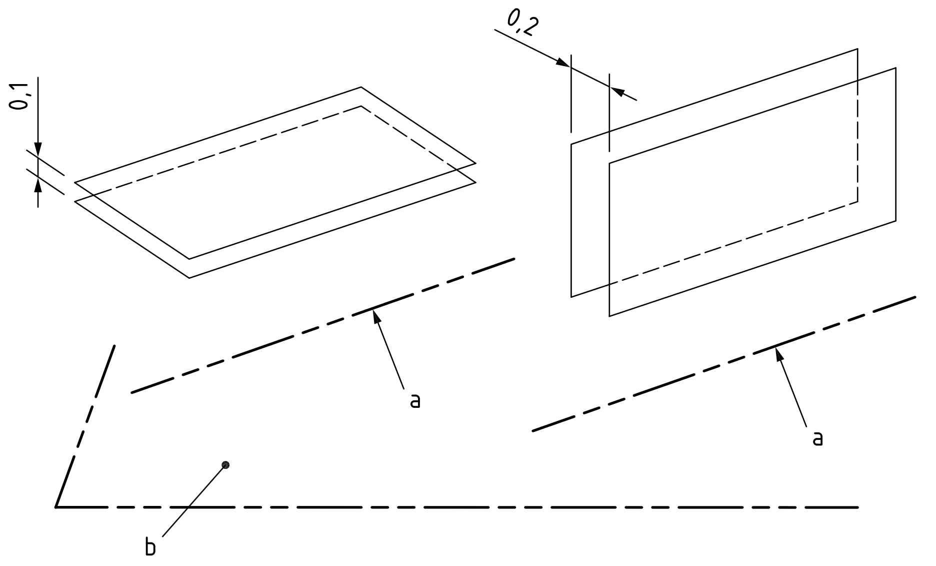


Figure 50 **Tolerances perpendicular to each other**



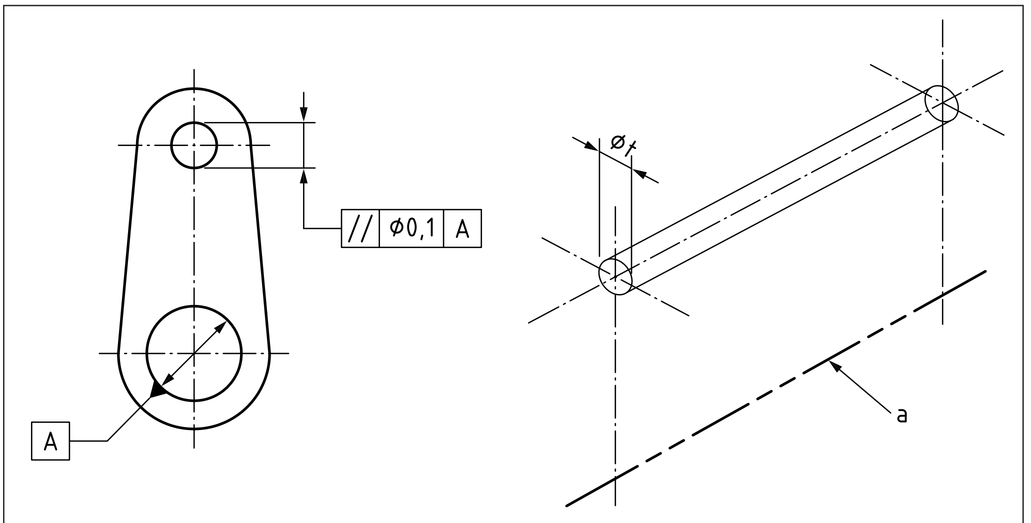
Key

a Datum A

b Datum B

The tolerance zone shall be cylindrical [(see Figure 51 a) and 51 b)] or circular if the tolerance value is preceded by the symbol "Ø" or spherical if it is preceded by the symbol "SØ".

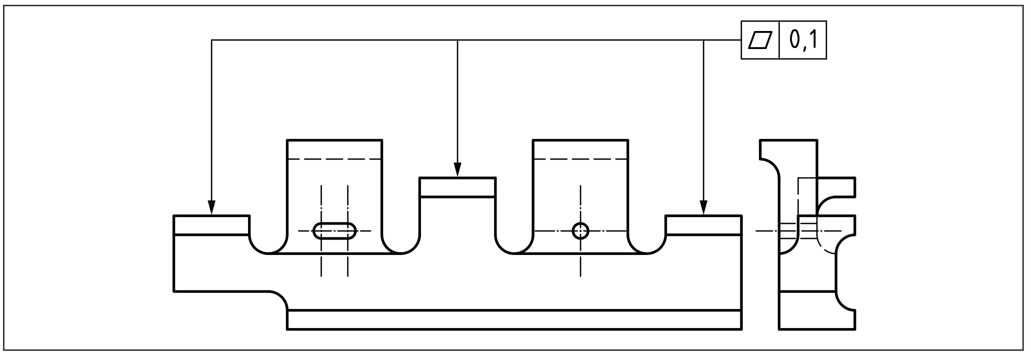
Figure 51 **Cylindrical and circular tolerance zones**



a) Drawing indication b) Interpretation

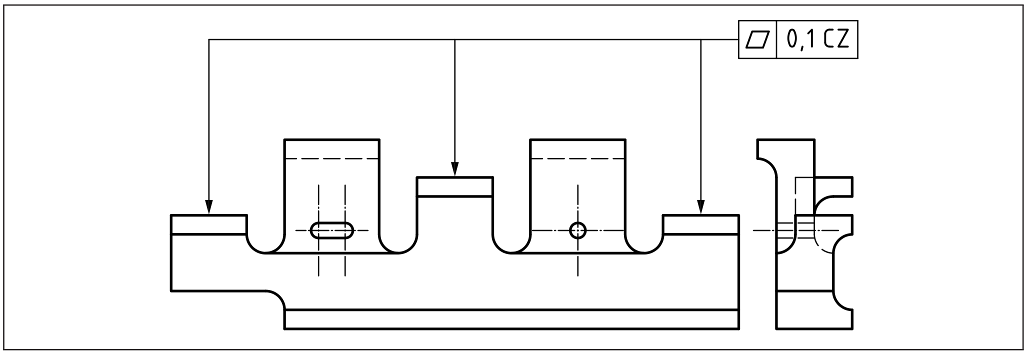
NOTE 2 Individual tolerance zones of the same value applied to several separate features can be specified (see Figure 52).

Figure 52 **Tolerance zones applied to separate features**



Where a single tolerance zone is applied to several separate features, the requirement shall be indicated by the symbol "CZ" for common zone following the tolerance in the tolerance frame (see Figure 53).

Figure 53 **Single tolerance zone applied to separate features**

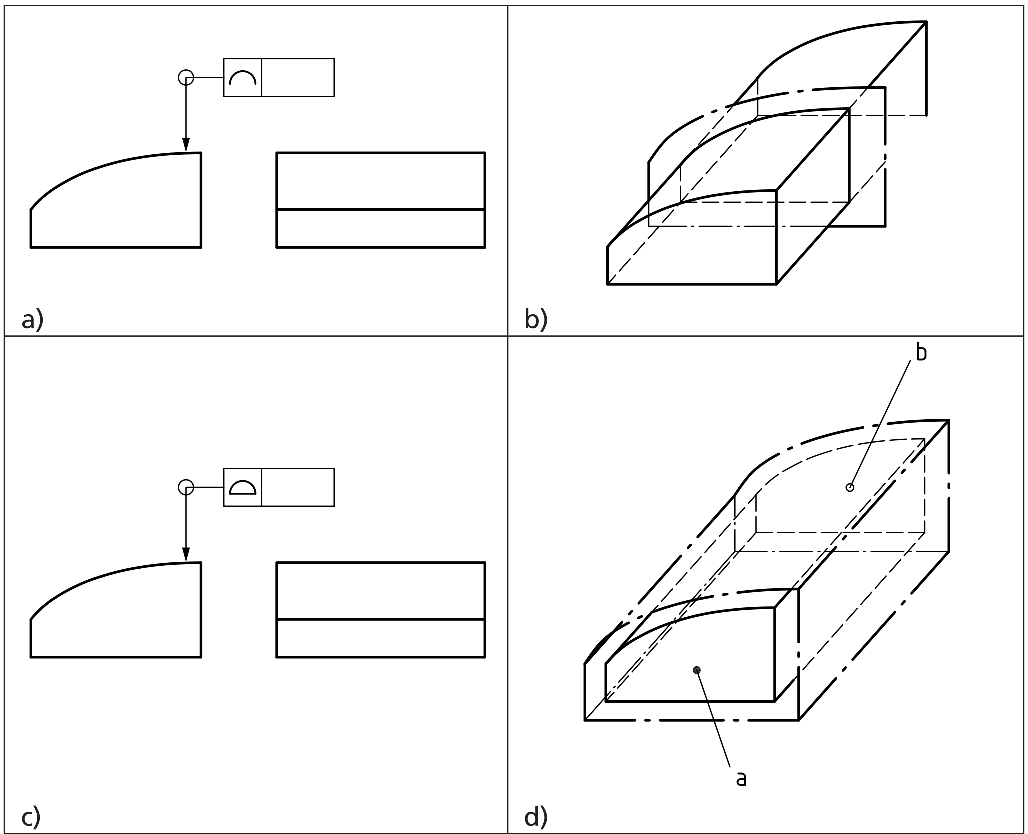


27.7 Supplementary indications

If a profile characteristic is applied to the entire outline of the cross-sections or if it is applied to the entire surface represented by the outline, it shall be indicated using the symbol "all around".

NOTE The all-around symbol does not involve the entire workpiece, but only the surfaces represented by the outline and identified by the tolerance indication (see Figure 54).

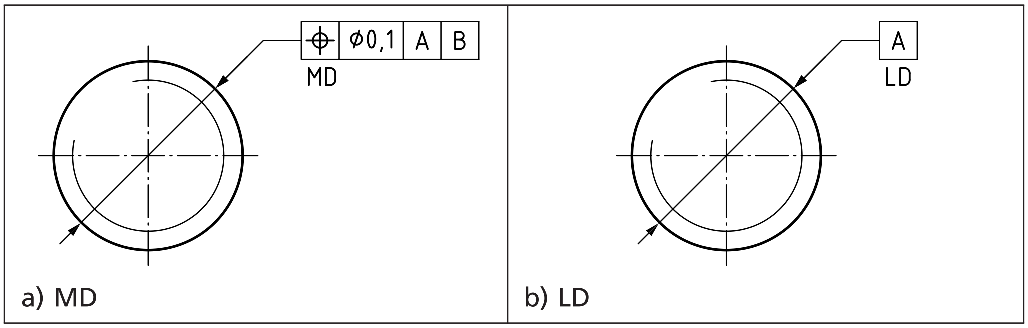
Figure 54 **Examples of the use of the "all around" symbol**



NOTE The long-dashed, short-dashed line indicates the considered features. Surfaces a and b are not considered in the specification.

Tolerances and datums specified for screw threads shall apply to the axis derived from the pitch cylinder, unless otherwise specified, e.g. "MD" for major diameter and "LD" for minor diameter (see example of Figure 55). Tolerances and datums specified for gears and splines shall designate the specific feature to which they apply, i.e. "PD" for pitch diameter, "MD" for major diameter or "LD" for minor diameter.

Figure 55 **Examples of "MD" and "LD"**



27.8 Theoretically exact dimensions (TED)

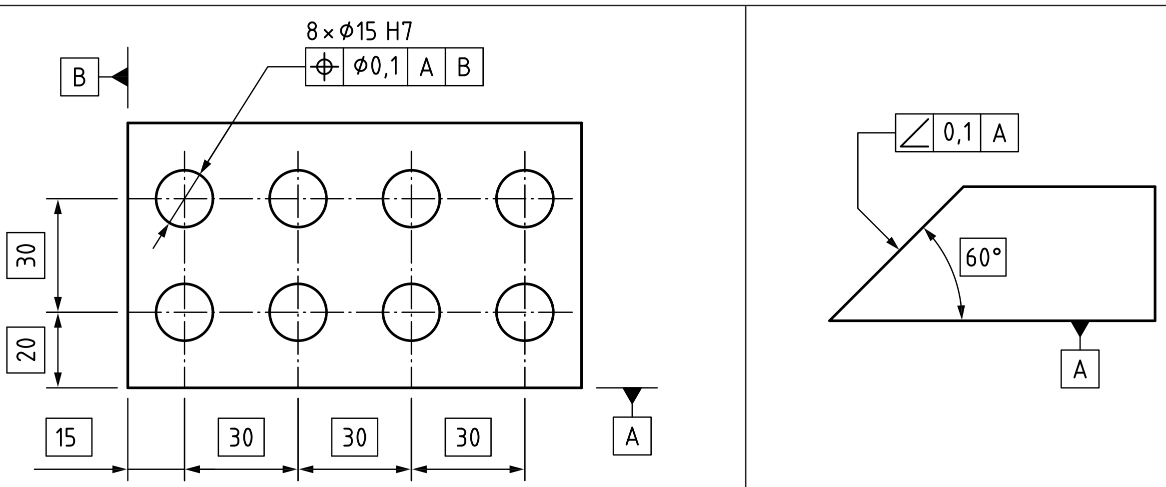
COMMENTARY ON ***27.8***

If tolerances of location, orientation or profile are prescribed for a feature or a group of features, the dimensions determining the theoretically exact location, orientation or profile respectively are called theoretically exact dimensions (TED).

TED also apply to the dimensions determining the relative orientation of the datums of a system.

TED shall not be toleranced. They shall be enclosed in a frame [see Figure 56 a) and 56b)].

Figure 56 **TED, enclosed in a frame**



a) b)

27.9 Restrictive specifications

If a tolerance of the same characteristic is applied to a restricted length, lying anywhere within the total extent of the feature, the value of the restricted length shall be added after the tolerance value and separated from it by an oblique stroke [see Figure 57 a)].

NOTE 1 If two or more tolerances of the same characteristic are to be indicated, they could be combined as shown in Figure 57 b).

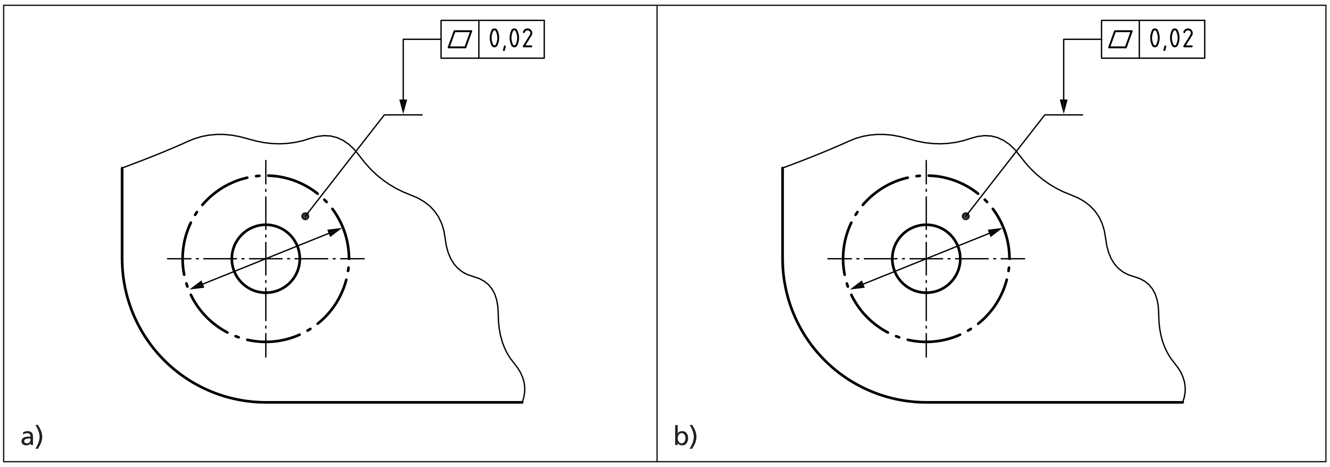
Figure 57 **Examples of tolerances of the same characteristic**

— | 0,05/200	— | 0,1 / 0,05/200
a) Single tolerance	b) Two or more tolerances

If a tolerance is applied to a restricted part of a feature only, this restriction shall be shown as a wide, long dashed-dotted line and dimensioned [see Figure 58 a) and 58 b)].

NOTE 2 See ISO 128-24:1999, Table 2.

Figure 58 **Tolerance applied to a restricted part of a feature**



NOTE 3 For information about the restricted part of a datum see BS EN ISO 1101:2005, ***9.4****.*

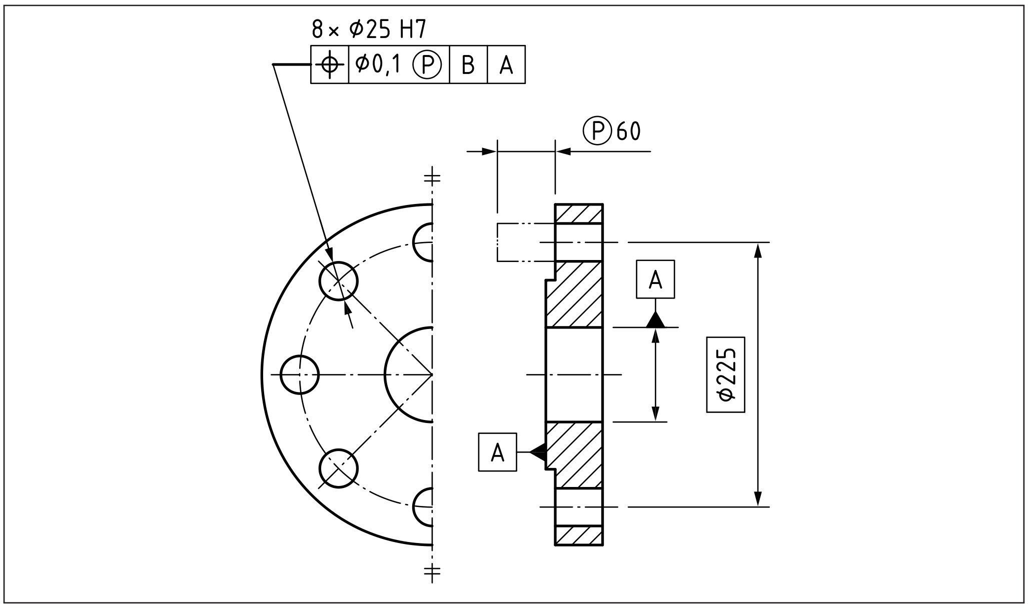
NOTE 4 Restrictions to the form of a feature within the tolerance zone are given in ***6.3*** *and BS EN ISO 1101:2005, Clause 7.*

27.10 Projected tolerance zone

Projected tolerance zones shall be indicated by the specification modifier symbol Ⓟ (see example of Figure 59).

NOTE See BS ISO 10578 for additional information.

Figure 59 **Projected tolerance zone**

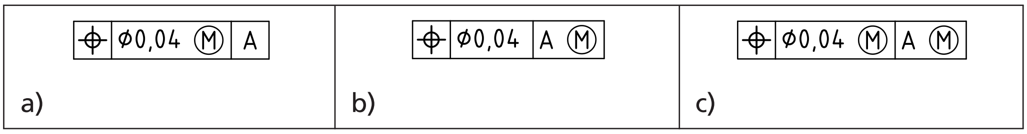


27.11 Maximum material requirement

The maximum material requirement shall be indicated by the specification modifier symbol Ⓜ. The symbol shall be placed after the specified tolerance value, datum letter or both as appropriate (see Figure 60).

NOTE See BS EN ISO 2692 for detailed rules.

Figure 60 **Indication of the maximum material requirement**

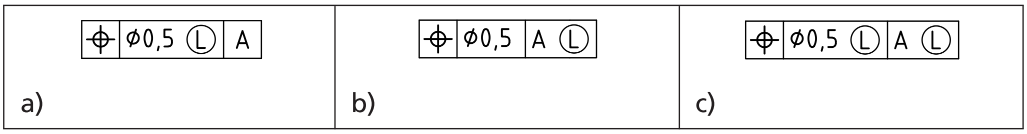


27.12 Least material requirement

The least material requirement shall be indicated by the specification modifier symbol Ⓛ. The symbol shall be placed after the specified tolerance value, datum letter or both as appropriate (see Figure 61).

NOTE See BS EN ISO 2692 for additional information.

Figure 61 **Indication of the least material requirement**

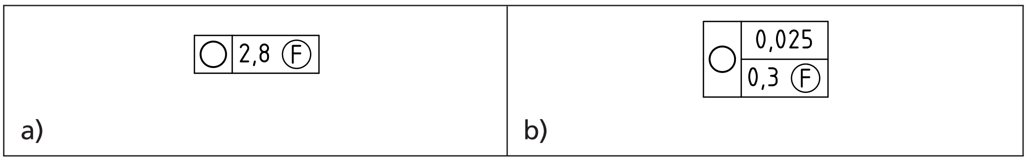


27.13 Free state condition

The free state condition for non-rigid parts shall be indicated by the specification modifier symbol Ⓕ placed after the specified tolerance value (see Figure 62).

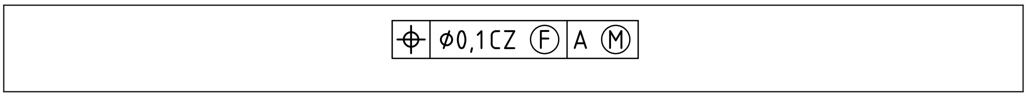
*NOTE 1 See **21.9** and BS ISO 10579 and BS EN ISO 1101 for additional information.*

Figure 62 **Free state condition**



NOTE 2 Several specification modifiers, e.g. Ⓟ, Ⓜ, Ⓛ, Ⓕ, CZ and ∠∅⌓ could be used simultaneously in the same tolerance frame (see Figure 63).

Figure 63 **Use of several specification modifiers**



27.14 Interrelationship of geometrical tolerances

*COMMENTARY ON **27.14***

For functional reasons, one or more characteristics can be toleranced to define the geometrical deviations of a feature. Certain types of tolerances, which limit the geometrical deviations of a feature, can also limit other types of deviations for the same feature.

Location tolerances of a feature shall control location deviation, orientation deviation and form deviation of this feature.

Orientation tolerances of a feature shall control orientation and form deviations of this feature.

Form tolerances of a feature shall only control form deviations of this feature.

28 Surface texture indication

*COMMENTARY ON CLAUSE **28***

BS 1134 offers an excellent introduction to surface texture specification.

Indication of surface texture shall conform to the following standards, as appropriate.

BS 1134	*Assessment of surface texture. Guidance and general information*
BS EN ISO 1302	*Geometrical Product Specifications (GPS) – Indication of surface texture in technical product documentation*

NOTE 1 The correct application of BS EN ISO 1302 requires the use of the following standards.

NOTE 2 Although it is not usual practice to make secondary references such as these, BS EN ISO 1302 itself is of such significance that it is considered appropriate to ensure their inclusion in the BS 8888 kits in this way.

BS EN ISO 8785	*Geometrical product specification (GPS) – Surface imperfections – Terms definitions and parameters*
BS EN ISO 3274	*Geometrical Product Specifications (GPS) – Surface texture: profile method – Nominal characteristics of contact (stylus) instruments*
BS EN ISO 4287	*Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters*
BS EN ISO 4288	*Geometrical Product Specification (GPS) – Surface texture – Profile method: Rules and procedures for the assessment of surface texture*
BS EN ISO 10135	*Technical drawings – Simplified representation of moulded, cast and forged parts*
BS EN ISO 11562	*Geometrical Product Specifications (GPS) – Surface texture: Profile method – Metrological characteristics of phase correct filters*
BS EN ISO 12085	*Geometrical Product Specifications (GPS) – Surface texture: Profile method – Motif parameters*
BS EN ISO 13565-1	*Geometric Product Specifications (GPS) – Surface texture: Profile method – Surfaces having stratified functional properties – Part 1: Filtering and general measurement conditions*
BS EN ISO 13565-2	*Geometrical Product Specifications (GPS) – Surface texture: Profile method – Part 2: Height characterization using the linear material ratio curve*
BS EN ISO 13565-3	*Geometrical Product Specifications (GPS) – Surface texture: Profile method – Part 3: Height characterization using the material probability curve*
BS EN 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*
BS EN ISO 14660-1	*Geometrical Product Specifications (GPS) – Geometrical features – Part 1: General terms and definitions*

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

NOTE 3 The following documents detail different aspects of filtering which could be utilized to process surface texture readings.

DD ISO/TS 16610-1	*GPS – Filtration – Part 1: Overview and basic concepts*
DD ISO/TS 16610-20	*GPS – Filtration – Part 20: Linear profile filters: Basic concepts*
DD ISO/TS 16610-22	*GPS – Filtration – Part 22: Linear profile filters: Spline filters*
DD ISO/TS 16610-29	*GPS – Filtration – Part 29: Linear profile filters: Spline wavelets*
DD ISO/TS 16610-40	*GPS – Filtration – Part 40: Morphological profile filters: Basic concepts*
DD ISO/TS 16610-41	*GPS – Filtration – Part 1: Morphological profile filters: Disk and horizontal line-segment filters*
DD ISO/TS 16610-49	*GPS – Filtration – Part 1: Morphological profile filters: Scale space techniques*

29 Graphical representation and annotation of 3-D data (3-D modelling output)

Graphical representation and annotation of 3-D models shall conform to the following standard.

BS ISO 16792	*Technical product documentation – Digital product definition – Data practices.*

30 Verification

30.1 Verification processes

Verification processes shall conform to the following standards, as appropriate.

BS EN ISO 14253-1	*GPS – Inspection by measurement of workpieces and measuring equipment – Part 1: Decision rules for proving conformance or non-conformance with specifications*
BS EN ISO 14253-2	*GPS – Inspection by measurement of workpieces and measuring equipment – Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification*
BS EN ISO 14253-3	*GPS – Inspection by measurement of workpieces and measuring equipment – Part 3: Guidelines for achieving agreements on measurement uncertainty statements*
DD ISO/TS 23165	*GPS – Guidelines for the evaluation of coordinate measuring machine (CMM) test uncertainty*

30.2 Verification devices

Verification devices shall conform to the following standards, as appropriate.

BS EN ISO 463	*Dimensional measuring equipment – Design and metrological characteristics of mechanical dial gauges*

BS 2795	*Specification for dial test indicators (lever type) for linear measurement*
BS EN ISO 14978	*GPS – General concepts and requirements for GPS measuring equipment.*
DD CEN/ISO TS 15530-3	*GPS – Coordinate measuring machines (CMM): Technique for determining the uncertainty of measurement – Part 3: Use of calibrated workpieces or standards*

31 Security

31.1 Introduction

Many TPSs have minimal requirements for security, other than that provided by general handling and storage procedures; however, where specific need for a general level of security is identified, users shall ensure that the requirements in **31.2**, **31.3** and **31.4** are met.

31.2 General security

Procedures for ensuring the security of TPDs and TPSs shall conform to the following standard.

BS EN ISO 11442	*Technical product documentation – Handling of computer-based technical information*

31.3 Enhanced security

Where enhanced security is claimed, the requirements of Annex D shall be met, in addition to those in **31.2**.

31.4 Security level identification

The level of security attributed to any given TPS shall be clearly identified by the relevant marking placed adjacent to the title or title block, of every TPD making up that TPS.

32 Storage and retrieval

Methods for storage and retrieval of the document shall conform to the following standards, as appropriate.

BS EN ISO 6428	*Technical drawings – Requirements for microcopying*
BS EN ISO 11442	*Technical product documentation – Handling of computer-based technical information*

33 Marking

33.1 General

Technical product documents shall be marked to indicate which standards, or system of standards, should govern their interpretation in a prominent location. [3)]

Technical product documents prepared in accordance with the requirements of this British Standard shall be prepared in accordance with the ISO system.

*NOTE The marking of a TPD or TPS with the number of this standard constitutes a claim that the appropriate requirements of all relevant cross-referenced standards, in addition to the requirements directly stated in this British Standard, have been met. Attention is drawn to the acceptance date principle (**4.2.3**).*

33.2 BS 8888 – Enhanced security

Technical product documents prepared in accordance with the requirements of this British Standard and meeting the requirements for enhanced security specified in Annex D, shall be marked with the number of this standard followed by a suffix "/D", i.e.

CONFORMS TO BS 8888/D

in a prominent location.

*NOTE The /D marking to indicate enhanced security requirements should not be confused with the triangle D symbol (see **33.3**), which was formerly used to invoke the dependency system of tolerancing.*

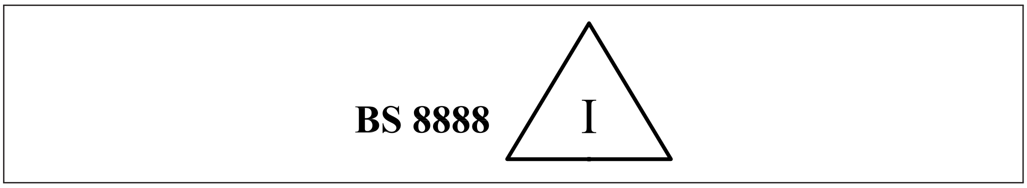
33.3 Tolerancing system

*COMMENTARY ON **33.3***

It was former practice to mark a TPS with the indication "BS 8888" supplemented by the letter "I" contained within an equilateral triangle (see Figure 64) or the letter "D" contained within an equilateral triangle (see Figure 65).

The triangle 'I' symbol was taken to indicate that the Principle of Independency was to be used to govern the interpretation of size and form requirements. While this had the same meaning as "TOLERANCING ISO 8015", its meaning might not be apparent to an interpreter who was familiar with ISO standards, but not BS 8888, so its use is no longer recommended.

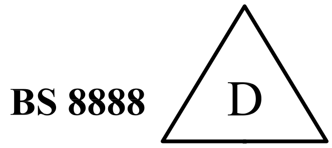
Figure 64 **BS 8888 independency system symbol**



[3)] Marking BS 8888:2011 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

The triangle 'D' symbol was taken to indicate that the Principle of Dependency was to be used to govern the interpretation of size and form requirements. While this was included to maintain consistency with earlier versions of BS 8888 and BS 308, the interpretation of the Principle of Dependency as a general requirement is not fully defined within the ISO system, so there may be ambiguities in its interpretation. In view of such possible ambiguities, and the fact that the symbol might not be understood by interpreters who were familiar with the ISO system but not BS 8888, the use of this symbol is no longer recommended.

Figure 65 **BS 8888 dependency system symbol**



Where the TPD or TPS has been prepared using the ISO system for the interpretation of size and form, the drawing shall carry the following statement in, or close to, the title block:

TOLERANCING ISO 8015

34 Protection notices

COMMENTARY ON CLAUSE ***34***

It is suggested that where it is considered appropriate to place restrictions on the use of technical product documentation, the recommendations contained in the following standard be applied.

BS ISO 16016 *Technical product documentation – Protection notices for restricting the use of documents and products*

Annex A (normative) Normative references

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

BIP 2155, *The essential guide to technical product specification – Engineering drawing*

BS 1916-1, *Limits and fits for engineering – Part 1: Guide to limits and tolerances*

BS 1916-2, *Limits and fits for engineering – Part 2: Guide to the selection of fits in BS 1916-1*

BS 1916-3, *Limits and fits for engineering – Part 3: Guide to tolerances, limits and fits for large diameters*

BS 2917-1, *Graphic symbols and circuit diagrams for fluid power systems and components – Part 1: Specification for graphic symbols*

BS 3238-1, *Graphical symbols for components of servo-mechanisms – Part 1: Transductors and magnetic amplifiers*

BS 3238-2, *Graphical symbols for components of servo-mechanisms – Part 2: General servo-mechanisms*

BS 4500, *Limits and fits – Guidance for system of cone (taper) fits and tolerances for cones from C = 1:3 to 1:500, lengths from 6 mm to 630 mm and diameters up to 500 mm*

BS 5070-1, *Engineering diagram drawing practice – Part 1: Recommendations for general principles*

BS 5070-3, *Engineering diagram drawing practice – Part 3: Recommendations for mechanical/fluid flow diagrams*

BS 5070-4, *Engineering diagram drawing practice – Part 4: Recommendations for logic diagrams*

BS 6615, *Specification for dimensional tolerances for metal and metal alloy castings*

BS 7010, *Code of practice for a system of tolerances for the dimensions of plastic mouldings*

BS EN 20286-1, *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits*

BS EN 20286-2, *ISO system of limits and fits – Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

BS EN 22553, *Welded, brazed and soldered joints – Symbolic representation on drawings*

BS EN 61082-2, *Preparation of documents used in electrotechnology – Part 2: Function-oriented diagrams*

BS EN 80000-13, *Quantities and units – Part 13: Information science and technology*

BS EN 80000-14, *Quantities and units – Part 14: Telebiometrics related to human physiology*

BS EN ISO 1, *Geometrical product specifications (GPS) – Standard reference temperature for geometrical product specification and verification*

BS EN ISO 128-20, *Technical drawings – General principles of presentation – Part 20: Basic conventions for lines*

BS EN ISO 128-21, *Technical drawings – General principles of presentation – Part 21: Preparation of lines by CAD systems*

BS EN ISO 1101:2005, [4] *Technical drawings – Geometrical tolerancing – Tolerances of form, orientation, location and run-out*

BS EN ISO 1119, *Geometrical product specifications (GPS) – Series of conical tapers and taper angles*

BS EN ISO 1302, *Geometrical Product Specifications (GPS) – Indication of surface texture in technical product documentation*

BS EN ISO 1660, *Technical drawings – Dimensioning and tolerancing of profiles*

BS EN ISO 2162-1, *Technical product documentation – Springs – Part 1: Simplified representation*

BS EN ISO 2162-2, *Technical product documentation – Springs – Part 2: Presentation of data for cylindrical helical compression springs*

BS EN ISO 26909, Springs – Vocabulary

BS EN ISO 2203, *Technical drawings – Conventional representation of gears*

BS EN ISO 2692, *Geometrical product specifications (GPS) – Geometrical tolerancing –Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)*

BS EN ISO 3098-0, *Technical product documentation – Lettering – Part 0: General requirements*

BS EN ISO 3098-2, *Technical product documentation – Lettering – Part 2: Latin alphabet, numerals and marks*

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BS ISO 14617-6, *Graphical symbols for diagrams – Part 6: Measurement and control functions*

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Annex B (informative)

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5) Withdrawn.

Annex C (normative) Geometrical tolerancing

C.1 General

NOTE Examples of geometrical tolerances and requirements associated with them (according to BIP 2155) are shown in Table C.1.

Table C.1 **Examples of geometrical tolerancing**

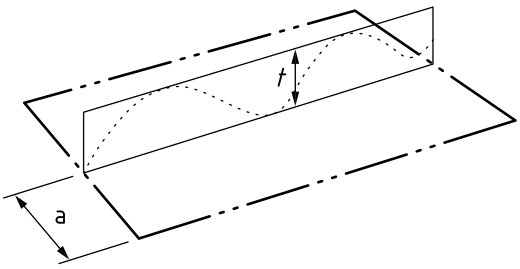
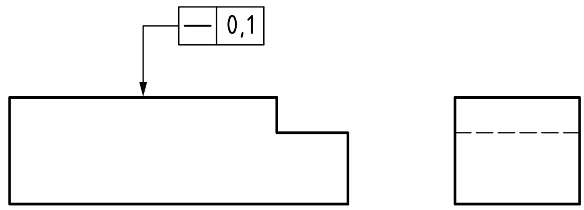
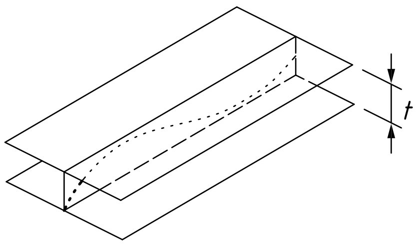
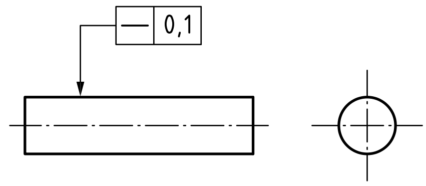
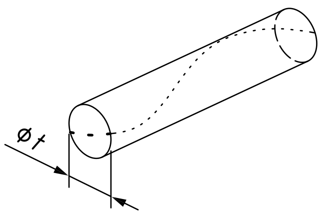
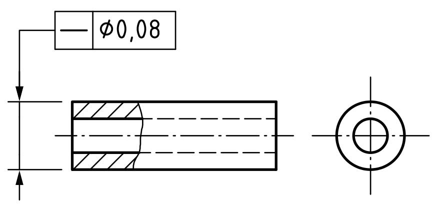
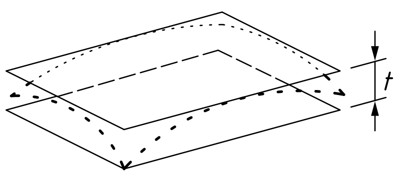
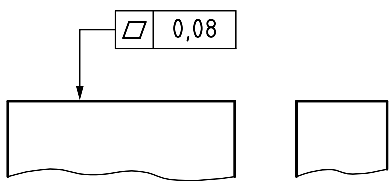
Symbol	Definition of the tolerance zone	Indication and explanation in 2D
	Straightness tolerance	
—	The tolerance zone, in the considered plane, shall be limited by two parallel straight lines a distance *t* apart and in the specified direction only (*a* = any distance). 	Any extracted (actual) line on the upper surface, parallel to the plane of projection in which the indication is shown, shall be contained between two parallel straight lines 0,1 apart. 
—	The tolerance zone shall be limited by two parallel planes a distance *t* apart. 	Any extracted (actual) generating line on the cylindrical surface shall be contained between two parallel planes 0,1 apart. 
—	The tolerance zone shall be limited by a cylinder of diameter *t*, if the tolerance value is preceded by the symbol Ø. 	The extracted (actual) median line of the cylinder to which the tolerance applies shall be contained within a cylindrical zone of diameter 0,08. 
	Flatness tolerance	
⏥	The tolerance zone shall be limited by two parallel planes a distance *t* apart. 	The extracted (actual) surface shall be contained between two parallel planes 0,08 apart. 

Table C.1 **Examples of geometrical tolerancing**

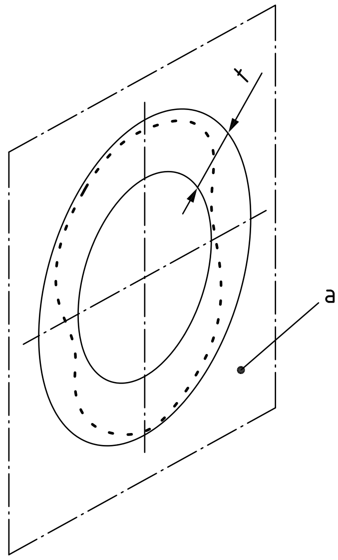
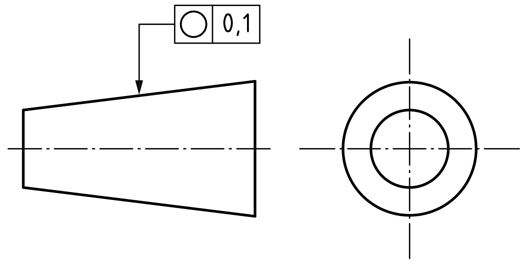
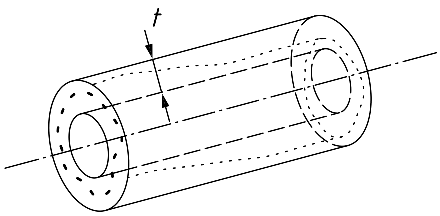
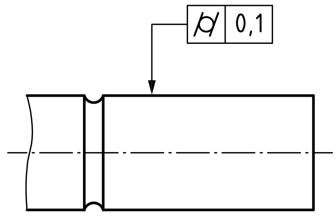
Symbol	**Definition of the tolerance zone**	**Indication and explanation in 2D**
		Roundness tolerance
○	The tolerance zone, in the considered cross-section, shall be limited by two concentric circles with a difference in radii of *t* (*a* = any cross-section). 	The extracted (actual) circumferential line in any cross- section of the conical surface, shall be contained between two co-planar concentric circles with a difference in radii of 0,1. 
		Cylindricity tolerance
⌭	The tolerance zone shall be limited by two coaxial cylinders with a difference in radii of *t*. 	The extracted (actual) cylindrical surface shall be contained between two coaxial cylinders with a difference in radii of 0,1. 

Table C.1 **Examples of geometrical tolerancing**

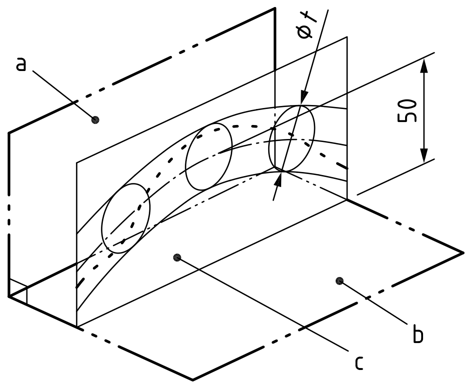
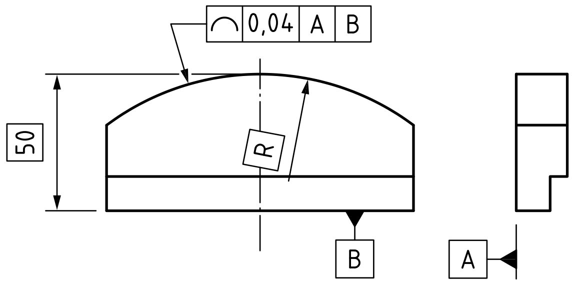
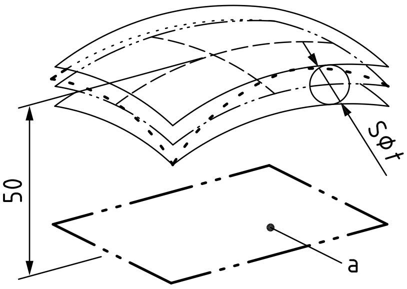
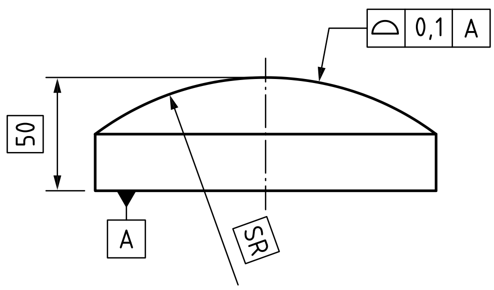
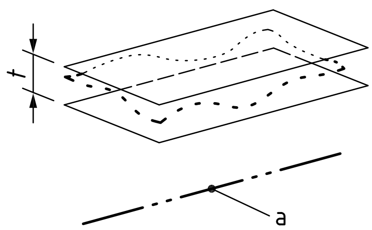
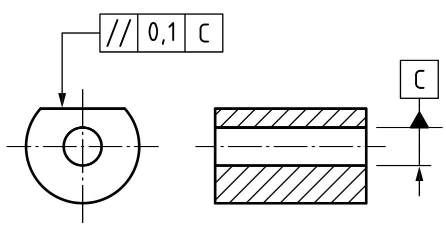
Symbol	**Definition of the tolerance zone**	**Indication and explanation in 2D**
	Profile tolerance of a line related to a datum system	
⌒	The tolerance zone shall be limited by two lines enveloping circles of diameter *t*, the centres of which are situated on a line having the theoretically exact geometrical form with respect to datum plane A and datum plane B.  *NOTE a = datum A; b = datum B; c = plane parallel to datum A.*	In each section, parallel to the plane of projection in which the indication is shown, the extracted (actual) profile line shall be contained between two equidistant lines enveloping circles of diameter 0,04, the centres of which are situated on a line having the theoretically exact geometrical form with respect to datum plane A and datum plane B. 
	Profile tolerance of a surface related to a datum	
⌓	The tolerance zone shall be limited by two surfaces enveloping spheres of diameter *t*, the centres of which are situated on a surface having the theoretically exact geometrical form with respect to datum plane A (a = datum A). 	The extracted (actual) surface shall be contained between two equidistant surfaces enveloping spheres of diameter 0,1, the centres of which are situated on a surface having the theoretically exact geometrical form with respect to datum plane A. 
	Parallelism tolerance of a surface related to a datum line	
//	The tolerance zone shall be limited by two parallel planes a distance *t* apart and parallel to the datum (a = datum C). 	The extracted (actual) surface shall be contained between two parallel planes 0,1 apart which are parallel to the datum axis C. 

Table C.1 **Examples of geometrical tolerancing**

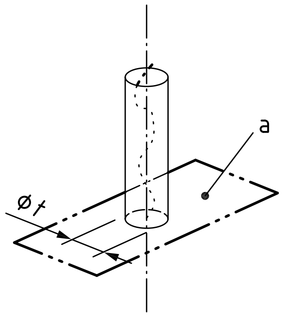
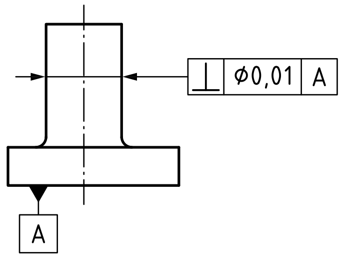
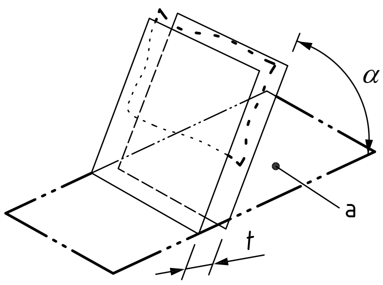
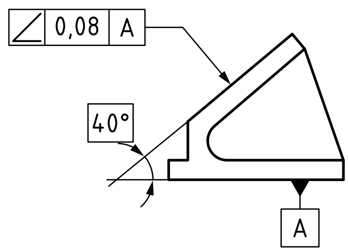
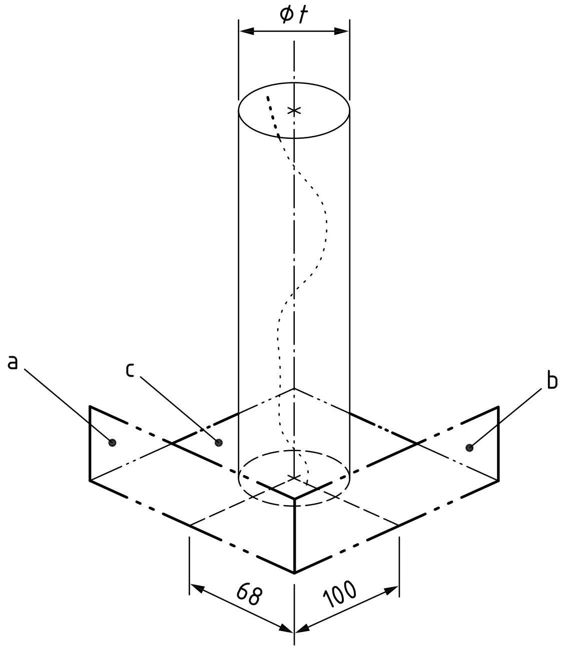
<table>
<tr><th>Symbol</th><th>Definition of the tolerance zone</th><th>Indication and explanation in 2D</th></tr>
<tr><td colspan="3">Perpendicularity tolerance of a line related to a datum surface</td></tr>
<tr><td>⊥</td><td>The tolerance zone shall be limited by a cylinder of diameter t perpendicular to the datum if the tolerance value is preceded by the symbol Ø (a = datum A).
</td><td>The extracted (actual) median line of the cylinder shall be within a cylindrical zone of diameter 0,01 perpendicular to datum plane A.
</td></tr>
<tr><td colspan="3">Angularity tolerance of a surface related to a datum surface</td></tr>
<tr><td>∠</td><td>The tolerance zone shall be limited by two parallel planes a distance t apart and inclined at the specified angle to the datum (a = datum A).
</td><td>The extracted (actual) surface shall be contained between two parallel planes 0,08 apart that are inclined at a theoretically exact angle of 40° to datum plane A.
</td></tr>
</table>

Table C.1 **Examples of geometrical tolerancing**

<table>
<tr><th>Symbol</th><th>Definition of the tolerance zone</th><th>Indication and explanation in 2D</th></tr>
<tr><td colspan="3">Positional tolerance of a line</td></tr>
<tr><td>⌖</td><td>The tolerance zone shall be limited by a cylinder of diameter t if the tolerance value s preceded by the symbol Ø. The axis of the tolerance cylinder shall be fixed by theoretically exact dimensions with respect to the datums C, A and B.


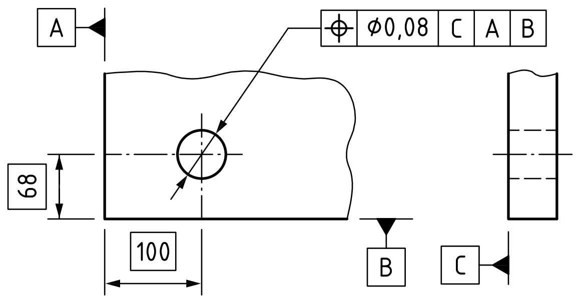
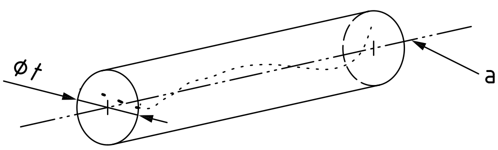
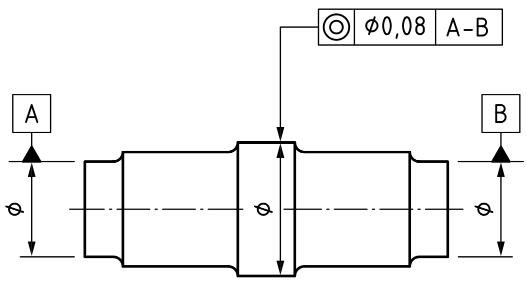
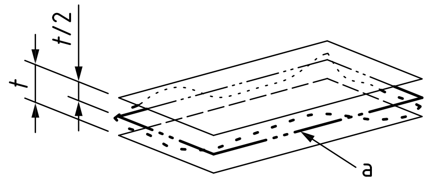
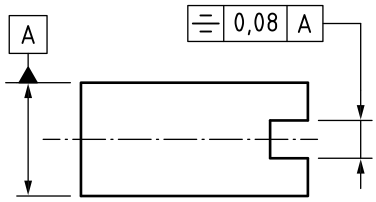
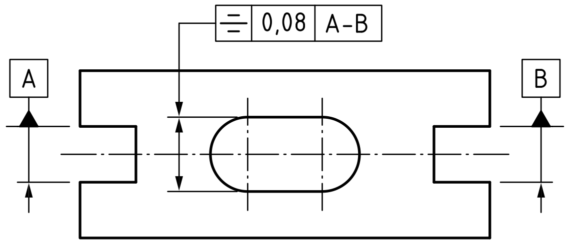
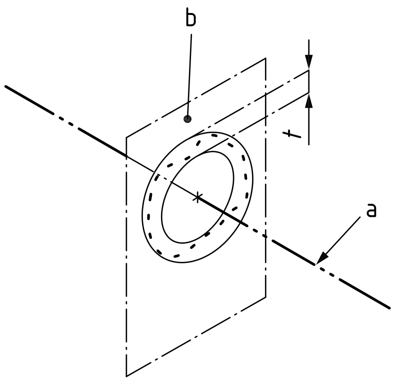
NOTE a = datum A; b = datum B; c = datum C.</td><td>The extracted (actual) median line shall be within a cylindrical zone of diameter 0,08, the axis of which coincides with the theoretically exact position of the considered hole, with respect to datum planes C, A and B.

</td></tr>
<tr><td colspan="3">Coaxiality tolerance of an axis</td></tr>
<tr><td>◎</td><td>The tolerance zone shall be limited by a cylinder of diameter t; the tolerance value shall be preceded by the symbol Ø. The axis of the cylindrical tolerance zone coincides with the datum (a = datum A–B).

</td><td>The extracted (actual) median line of the toleranced cylinder shall be within a cylindrical zone of diameter 0,08 the axis of which is the common datum straight line A–B.

</td></tr>
</table>

Table C.1 **Examples of geometrical tolerancing**

<table>
<tr><th>Symbol</th><th>Definition of the tolerance zone</th><th>Indication and explanation in 2D</th></tr>
<tr><td colspan="3">Symmetry tolerance of a median plane</td></tr>
<tr><td>⌯</td><td>The tolerance zone shall be limited by two parallel planes a distance t apart, symmetrically disposed about the median plane, with respect to the datum (a = datum).

</td><td>The extracted (actual) median surface shall be contained between two parallel planes 0,08 apart which are symmetrically disposed about the datum median plane A.


The extracted (actual) median surface shall be contained between two parallel planes 0,08 apart and symmetrically disposed about the common datum plane A–B.

</td></tr>
<tr><td colspan="3">Circular run-out tolerance – Radial</td></tr>
<tr><td>↗</td><td>The tolerance zone shall be limited within any cross-section perpendicular to the datum axis by two concentric circles with a difference in radii of t, the centres of which coincide with the datum.


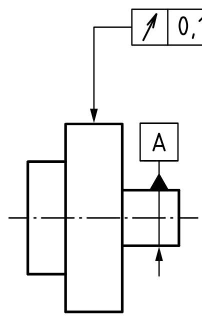
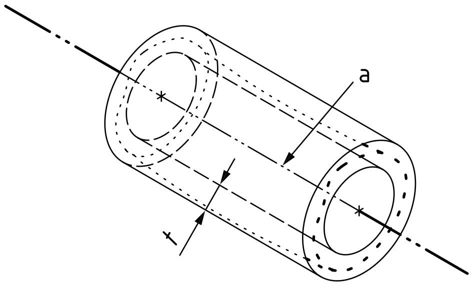
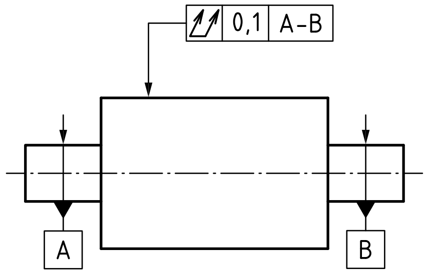
NOTE a = datum; b = cross-section plane.</td><td>The extracted (actual) line in any cross-section plane perpendicular to datum axis A shall be contained between two coplanar concentric circles with a difference in radii of 0,1.

</td></tr>
</table>

Table C.1 **Examples of geometrical tolerancing**

Symbol	Definition of the tolerance zone	Indication and explanation in 2D
	Total radial run-out tolerance	
⌰	The tolerance zone shall be limited by two coaxial cylinders with a difference in radii of *t*, the axes of which coincide with the datum (a = datum A–B). 	The extracted (actual) surface shall be contained between two coaxial cylinders with a difference in radii of 0,1 and the axes coincident with the common datum straight line A–B. 

Annex D (normative) Document security – Enhanced

D.1 Enhanced security

Where requirements for enhanced security are known to exist, the procedures identified in this annex shall be applied in addition to those specified in Clause **31**.

D.2 Identification of security classification

Any required security classification and/or caveat, shall be inserted in the TPS, immediately after classified information is incorporated.

Each sheet shall be classified according to its content.

The security classification shall always appear at the top and bottom of A4 sheets and at the top left and bottom right hand corners of sheets larger than A4.

The security classification shall either be:

a) larger than the largest text used in the TPS; or

b) bolder and the same size as the largest text used in the TPS.

D.3 Marking for enhanced security

Technical product document sets, prepared in accordance with the requirements of this Annex shall be identified by the addition of the suffix "/D" to the number of this standard, i.e. "BS 8888/D", [6] in a prominent location.

[6] Marking BS 8888:2011 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

Annex E (informative) Technical product specification – Geometrical product specification (GPS)

E.1 Background

Over the course of the 20th century, with the advent of mass production, the need to be able to manufacture parts to a specification with a high degree of repeatability became more important than ever before. This led to a formalization of the methods used to specify work pieces through the use of engineering drawings with dimensions and tolerances, and the development of new methods to specify geometrical characteristics (geometrical tolerancing) and surface texture (i.e. roughness values).

Most industrialized countries developed national standards to govern the methods used for engineering specifications, giving rise to BS 308 in the UK, and ASME Y14.5 [1] standard in America, as well as similar standards in many other countries. The evolution and development of these methodologies has continued throughout this period and into the 21st century, with standards being added, extended and revised accordingly.

Under the ISO banner, the standards organizations from many different nations have worked together to develop and harmonize the different standards used for engineering specifications, and to encourage a common approach, with a view to improving communications and addressing the needs of a more global economy.

As a consequence of the way in which methodology has evolved and developed over the last 80 or so years, there are many areas in which the standards for engineering specifications are (or at least have been) ambiguous, inadequate, incomplete and even contradictory. These issues have been highlighted by several developments, including:

- improvements to the accuracy with which a work piece can be manufactured;
- improvements to the accuracy with which a work piece can be measured or inspected;
- the trend in the developed world to focus on design and assembly, subcontracting component manufacture to suppliers who are often overseas, and might not speak the same language (this trend in particular has removed the option of the informal communication or “understanding” that would often exist between design and manufacturing when they were neighbouring departments in the same company); and
- the requirements of CAD, CAM and CAQ system architects for formal mathematical definitions of all specification and verification operations that can be coded into software.

In response to this situation, ISO initiated a project in the early 1990s with the aim of developing a coherent, comprehensive and complete system for the specification of work piece geometry. This system is called geometrical product specification (GPS).

As its name suggests, GPS is concerned with the geometry of parts; it is not concerned with material properties or operating conditions. Specifically, GPS is concerned with the specification and verification of sizes, shapes and surface characteristics of a work piece to ensure functional requirements are met.

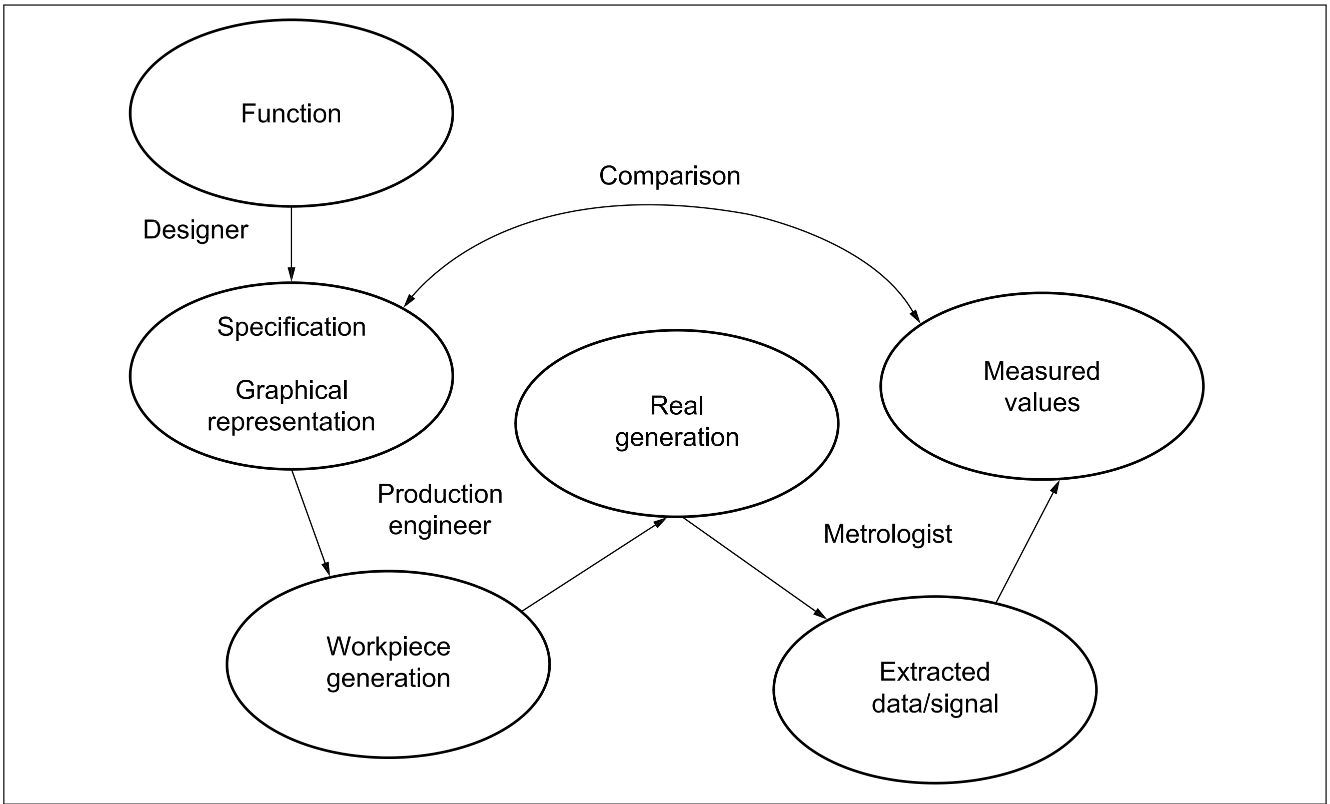
GPS is a new approach to product specification; but it builds on existing tools, and particularly the use of datums, geometrical tolerancing and surface texture tolerancing. GPS systematizes and extends these existing tools into a new methodology.

E.2 Key concepts

E.2.1 Different worlds or models

The GPS approach is based on the concept that any given work piece exists in several different "worlds", or as several different versions, at the same time (see Figure E.1). There is the "specification model", produced by the designer to represent the design intent or functional requirement; there is the actual manufactured work piece; and there is the "verification model", representing the metrological data extracted from the model by various measurement processes. The verification model should be compared with the specification model in order to establish whether the work piece complies with its specification.

Figure E.1 **Model of the relationship between specification, verification and the actual work piece**



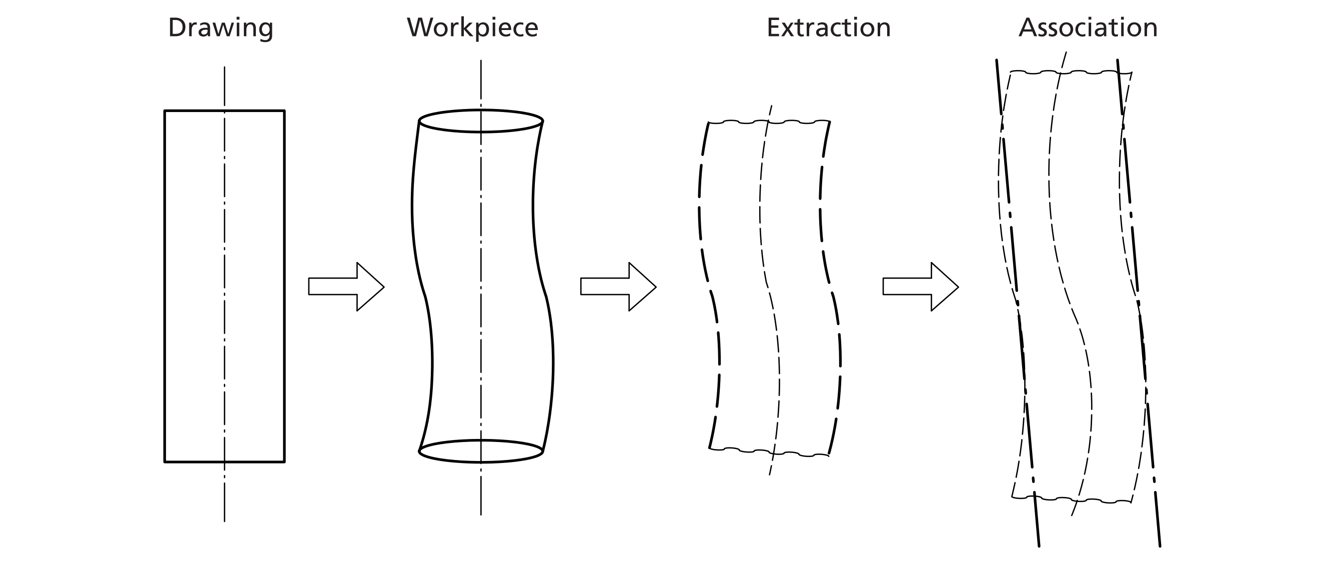
E.2.2 Specification and verification

E.2.2.1 General

One of the objectives of GPS has been to strengthen and clarify the relationship between the specification process, where the work piece geometry is defined, and the verification process, where the work piece is checked against its specification. It clearly makes sense for the inspection or verification process to inspect, as directly as possible, whatever quantity has been specified. Where the inspection process cannot directly check what has been specified, then there is greater scope for errors, or greater "uncertainty" in the process.

When a work piece is inspected or verified, a number of processes take place (see Figure E.2). These processes have been classified as partition, extraction, filtration, association, collection and construction. Much of the time, these processes are not consciously classified.

Figure E.2 **The link between design intent and metrology**



E.2.2.2 Partition

A work piece is "partitioned", or broken down, into a number of real, integral features (actual surfaces). In other words, work pieces are a collection of individual surfaces – flat surfaces, cylindrical surfaces, curved surfaces, etc.

E.2.2.3 Extraction

Having partitioned a work piece into a number of real, integral features, data should be extracted from them so that they can be quantified, measured or located. The real, integral feature can be defined as a set of an infinite number of points, defining the surface that separates the work piece from its surroundings within the extents of that particular feature. When measuring or sampling a real integral feature, users should not measure or sample an infinite number of points, but compromise and sample a finite number. The extracted, integral feature thus consists of a finite number of points

E.2.2.4 Filtration

In practice, extraction on its own is not sufficient to give a useful set of data representing the integral feature under consideration. In addition to extraction, data should be filtered to remove noise and unwanted detail.

E.2.2.5 Association

Having obtained an extracted model of the real, integral feature, consisting of a filtered and finite number of points, a verification process might be required to check the form (i.e. straightness), orientation (i.e. perpendicularity) or location of a derived feature (axis, median plane or centre point) based on that integral feature. In order to do this, a theoretically perfect geometrical form, corresponding to the nominal form in the specification model (i.e. a perfect cylinder, perfect set of parallel opposed planes, perfect sphere, cone or wedge) should be fitted to, or associated with, the extracted data. This is known as the associated integral feature.

E.2.2.6 Collection

In additional to the above operations, features sometimes need to be treated as a group or pattern of features. Groups or patterns of holes are a common example of this. Collection is the process of grouping these features together.

E.2.2.7 Construction

Sometimes tolerances can be applied to features which are dependent on, or resultants of, other features. A construction operation is used to determine the toleranced feature. For instance, straightness might be applied to an edge, the edge being defined as the intersection of two planes. The edge is constructed from the two extracted planar features.

E.2.3 The operator principle and the duality principle

The fact that these processes of partition, extraction, filtration, association, collection and construction take place during verification is of some consequence to the specifier. For instance, the designer or specifier can apply a flatness tolerance to a surface. In theory, that flatness requirement is applied to the entire set of an infinite number of points which comprise the real, integral surface. However, the verifier is going to check an extracted, integral surface, consisting of a finite number of points, which has been filtered to remove noise and unnecessary detail. The density of the extracted data, and the wavelength of the filters which have been used, are clearly bound to influence the results.

For this reason, the GPS approach requires these processes to be taken into account when specifying a work piece requirement to the same extent that they will be required for its verification. This concept, that the verification process and the specification process should mirror each other, or be duals of each other, is known is the *duality principle* (see Figure E.3).

To some extent this already happens. Partition takes place automatically, as work pieces are modelled, or drawn, as a collection of discrete features. Collection also takes place routinely, as dimensions, tolerances or notes are used to indicate when several features are to be treated as a group or pattern of features. Construction again takes place quite automatically, as edges and vertices appear where defined surfaces meet and intersect.

The processes of extraction and filtration, however, are normally left to the discretion of the verifier. The designer specifies the requirement for a real surface, the verifier checks it on the extracted surface and choose a sampling density and filtering function based on factors such as experience, informal understanding of the design requirements, in-house procedures, time available, equipment capabilities and limitations, mood, whim, etc. Under the GPS approach, this is no longer the same. The specifier is required to define the sampling density and filtering function.

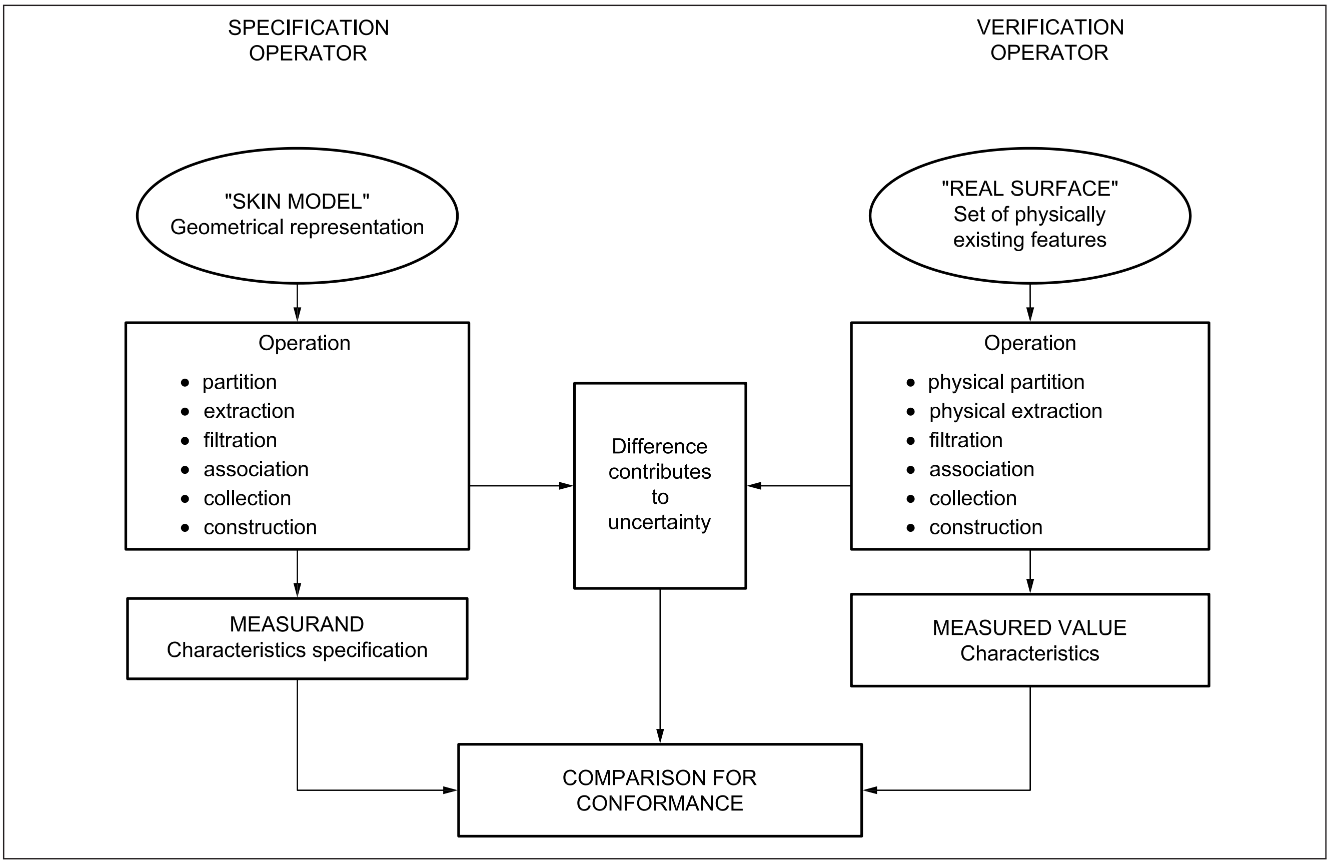
The process of association is also not normally considered by the designer or specifier. Association has to take place if the verifier is required, for example, to use the axis of a shaft as a datum, or to evaluate a positional tolerance on a hole. How the theoretically perfect associated feature is fitted to the extracted feature is again left to the verifier’s discretion. Mathematically, there are several ways in which this association can take place, including, for instance, the least squares method, the maximum inscribing method, and the minimum circumscribing method. Again, under the GPS approach, the appropriate method of association will need to be defined by the specifier.

Each element of the specification contains its own definitions for the processes of extraction, filtration and, where appropriate, association. Each specification element, which is known as a *specification operator*, is, in effect, a virtual measurement procedure, containing all the information that might be required for its verification (including datums, sampling densities, filtering values, and association methods). The verification operator is the physical implementation of that virtual measurement procedure defined in the specification. This is known as the *operator principle*.

The specification operator should not dictate the verification method, but merely provide all the information required in order that it can be verified.

So far, this approach has only been fully implemented in the annotation system used for defining surface texture. The annotations, definitions and values required to implement the GPS approach with geometrical tolerancing are still under development, and standards dealing with the different types of tolerance characteristic are gradually starting to appear.

Figure E.3 **The duality principle**



E.2.4 The default principle

This new approach might, at first glance, greatly increase the workload on the specifier, and greatly increase the volume of annotation required to properly define a work piece. In order to avoid both of these burdens, default values and methods are under preparation for the processes of extraction, filtration and association. Where the default values or methods are to be used, they should not be marked on the annotation. This is known as the *default principle*.

For example, if the designer specifies a location tolerance for a hole, the GPS approach requires the specification to include data on which association method, sampling density, and filtering techniques or values should be used. However, the GPS approach also provides default values for each of these items. The specifier can only produce annotation for these items where a value or method other than the default is required.

This means that in many, and probably almost all, cases, the full and complete annotation appears no different to the current annotation. The only difference is that the values and methods to be used when verifying the requirement are fully and unambiguously defined (by the default values and methods), and not left to the discretion of the verifier.

E.3 Uncertainty

E.3.1 General

A fundamental concept in the GPS system is that of "uncertainty". The concept of "uncertainty" is not new; it is an established fact of metrology. The uncertainty associated with a measurement can be thought of as representing how "good" the measurement is. If several measurements are taken of a length with a ruler, each measurement is likely to be slightly different. Consistency is achieved by recognizing the limitations of accuracy that can be achieved with a particular technique or piece of equipment, so no one would attempt to measure to accuracies of 0,01 mm with a ruler. The uncertainty associated with the ruler is a parameter that represents the range of possible values that could reasonably be obtained when measuring any given length with the ruler – this could be given as a simple value (perhaps 0,2 mm in this case), or a percentage, or a statistical quantity. Metrology equipment normally includes uncertainty values with the other data in its specification.

The GPS system extends this concept of uncertainty to the specification model as well as the verification model, and considers three different types of uncertainty.

E.3.2 Correlation uncertainty

Correlation uncertainty quantifies how well the work piece specification correlates to the functional requirements of the work piece. This uncertainty is the responsibility of the designer. Some of this uncertainty can be reduced or eliminated simply through professional competence, but some of it is inevitable. For instance, FEA techniques could be used to calculate the geometrical form of a structural component, but these calculations are approximations, and the operating conditions and material characteristics which the calculations are based on are themselves approximations and simplifications of the real-life situation.

E.3.3 Specification uncertainty

Specification uncertainty arises from the range of possible interpretations of a specification. This uncertainty is again the responsibility of the designer. As with correlation uncertainty, some of this uncertainty can be eliminated through professional competence (ensuring specifications are complete, effective use of datum systems, etc.). Specification uncertainty can arise not only from poor design or specification, but also from inherent ambiguities or incompleteness in standards. For instance, ISO standards do not state whether surface texture should be included or excluded when checking for geometrical variation. This incompleteness in the standard may result in a range of possible interpretations of a single tolerance specification. The manufacturer is entitled to choose any legitimate interpretation to work to.

E.3.4 Measurement uncertainty (attributed to the metrologist)

Measurement uncertainty has two aspects. The first is termed "method uncertainty", and this is to do with differences between the specification operator and the verification operator, in other words, this is to do with what measurements are taken. If the verification operator is a perfect implementation of the specification operator, there is no method uncertainty.

The second classification is termed "implementation uncertainty", which arises from deviations in the implementation of the verification operator, so this would include operator error, faulty equipment, etc.

E.3.5 Making use of uncertainty

Identifying sources of uncertainty has practical benefits, and quantifying uncertainty is a necessary aspect of specifying and verifying complete and unambiguous definitions of work piece geometry.

Identification of the sources of uncertainty can help with the allocation of resources. For instance, if correlation uncertainty is large, because component geometry is based on assumptions and highly approximate calculations, there would be little benefit in investing in highly accurate (and expensive) inspection equipment. Resources would be better targeted towards more accurate computer modelling and simulation, or acquiring more test data.

When values can be assigned to measurement uncertainty, this can then be taken into account when verifying the work piece. If checking to see whether tolerance limits have been complied with, then the each tolerance limit should be reduced by the amount of measurement uncertainty associated with the procedure. Where checking to see whether tolerance limits have been violated, each tolerance limit should be extended by the amount of measurement uncertainty associated with the procedure. Measurement uncertainty always "counts against" the verifier.

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