The Essential Guide to Technical Product Specification: Engineering Drawing

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British Standards

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Introduction

This guide has been produced as a companion to BS 8888, presenting up-to-date information based on the technical product specification aspects of BS 8888 and the essential standards it references.

Its aim is to offer straightforward guidance together with pictorial representations, to all practitioners of technical product specification, i.e. those currently using BS 8888 and those who, in a bid to conform to global ISO practices, are making or wish to make, the transition from the old BS 308 to BS 8888.

Its scope is to provide the necessary tools to enable engineers engaged in design specification, manufacturing and verification with the essential basic information required for specifying a product or component.

It includes comprehensive sections extracted from and referenced to international standards relating to linear, geometric and surface texture dimensioning and tolerancing, together with the practice of welding symbology, limits and fits and thread data. It also includes an illustrated index to all standards referenced in BS 8888.

This guide does not replace BS 8888 which is the definitive standard for technical product realization.

Any element of BS 8888 not included in this guide should not be considered as less important to technical specification than those included.

Most of the drawings in this guide have been extracted (and adapted) from the following BSI publications: BS EN ISO 1101, BS EN ISO 1302, BS ISO 5459, BS 8888 and PP 8888, Parts 1 and 2.

Chapter 1

Dimensioning and tolerancing of size

1.1 Introduction

Dimensioning is the process of applying measurements to a technical drawing. It is crucial to the whole process by which the designer will communicate the information required for the manufacture and verification of products.

1.2 General principles

Dimensions shall be applied to the drawing accurately, clearly and unambiguously. The following points shall be regarded as general dimensioning principles to be applied to all technical drawings.

- Each dimension necessary for the definition of the finished product shall be shown once only.
- Never calculate a dimension from the other dimensions shown on the drawing, nor scale the drawing.
- There shall be no more dimensions than are necessary to completely define the product.
- Preferred sizes shall be used whenever possible (see notes).
- Linear dimensions shall be expressed in millimetres (unit symbol 'mm'). If this information is stated on the drawing, the unit symbol 'mm' may be omitted. If other units are used, the symbols shall be shown with their respective values.
- Dimensions shall be expressed to the least number of significant figures, e.g. 45 not 45,0.
- The decimal marker shall be a bold comma, given a full letter space and placed on the baseline.
- Where four or more numerals are to the left or right of the decimal marker, a full space shall divide each group of three numerals, counting from the position of the decimal marker, e.g. 400 or 100 but 12 500 (see notes).
- A zero shall precede a decimal of less than one, e.g. 0,5.
- An angular dimension shall be expressed in degrees and minutes, e.g. 20° and 22° 30′ or, alternatively, as a decimal, e.g. 30,5°.
- A full space shall be left between the degree symbol and the minute numeral.
- When an angle is less than one degree, it shall be preceded by a zero, e.g. 0° 30′.

NOTES: Preferred sizes are those referring to standard material stock sizes and standard components such as nuts, bolts, studs and screws.

Decimal marker points or commas are not used to separate groups of numerals. This causes ambiguity since the decimal marker is denoted by a comma.

1.3 Types of dimension

For the purposes of this section, the following definitions apply.

dimension
numerical value expressed in appropriate units of measurement and indicated graphically on technical drawings with lines, symbols and notes

Dimensions are classified according to the following types.

functional dimension
dimension that is essential to the function of the piece or space (‘F’ in Figure 1). See also 1.14

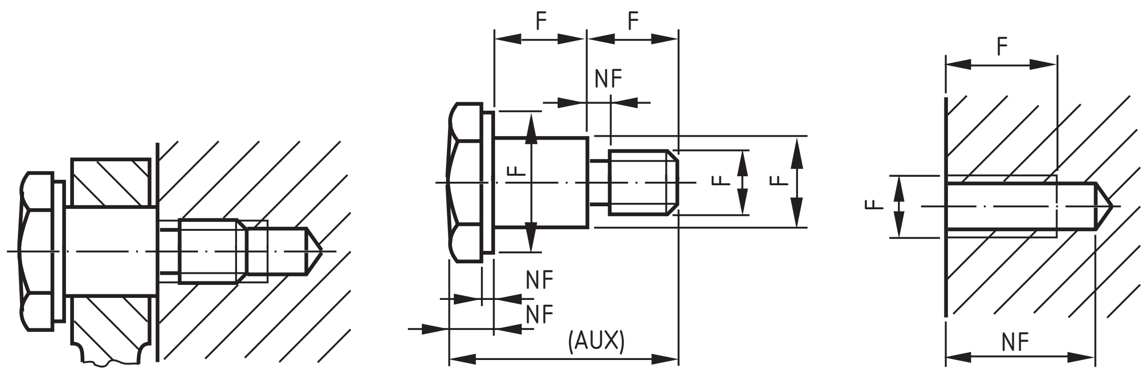
non-functional dimension
dimension that is not essential to the function of the piece or space (‘NF’ in Figure 1)

auxiliary dimension
Dimension, given for information purposes only, that does not govern production or inspection operations and is derived from other values shown on the drawing or in related documents

NOTE: An auxiliary dimension is given in parentheses and no tolerance may be applied to it (‘AUX’ in Figure 1).

feature
individual characteristic such as a flat surface, a cylindrical surface, two parallel surfaces, a shoulder, a screw thread, a slot or a profile

end product
complete part ready for assembly or service
or
configuration produced from a drawing specification
or
part ready for further processing (for example, a product from a foundry or forge) or a configuration needing further processing



(a) Design requirement (b) Shoulder screw (c) Threaded hole

Figure 1 – Types of dimensioning

1.4 Dimensioning conventions

Technical product specification standards specify the following conventions when dimensioning drawings.

Extension lines shall normally be placed outside the view to aid clarity, as shown in Figure 2.

The extension line connects the dimension line (on which the value of the measurement is placed) to the reference points on the outline of the drawing. The following standard practice is specified.

Crossing of extension lines shall be avoided whenever possible.

There should be a small gap between the outline of the drawing and a projection line. The extension line shall extend slightly beyond the dimension line, as shown in Figure 2.

Extension lines shall, where possible, be drawn at right angles to the dimension line.

Centre-lines, extensions of centre-lines and continuations of outlines shall never be used as dimension lines. They may, however, be used as projection lines.

Arrowheads and origin circles are commonly used as terminators for dimension lines. Oblique strokes and points can also be used, as shown in Figures 3 and 4.

Dimension lines shall be unbroken even if the feature they refer to is shown as interrupted, as illustrated in Figure 5.

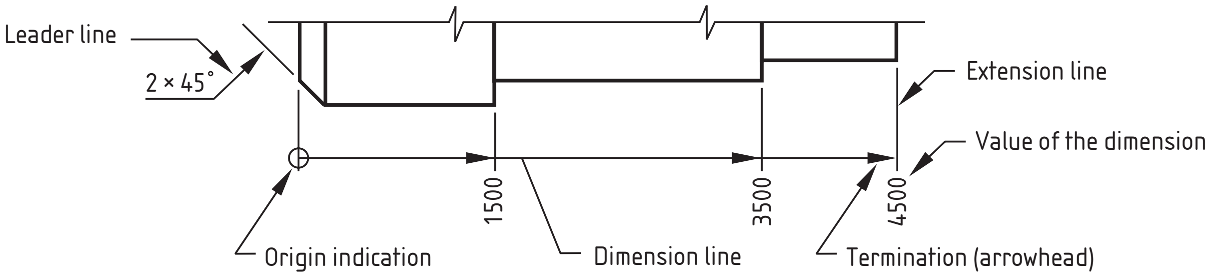


Figure 2 – Examples of extension lines and dimension lines

Terminators: dimension lines shall be terminated according to one of the representations shown in Figure 3.

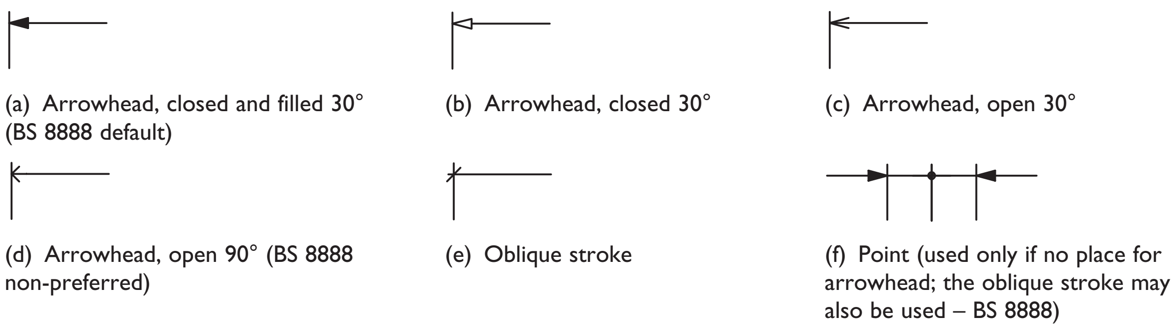


Figure 3 – Terminators for dimension lines

Origin indication: the origin of the dimension line shall be indicated as shown in Figure 4.

Figure 4 – Origin indication

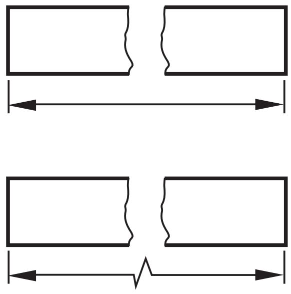


Figure 5 – Dimensioning interrupted features

When symmetrical parts are drawn partially, the portions of the dimension lines shall extend a short way beyond the axis of symmetry and the second termination shall be omitted, as shown in Figure 6.

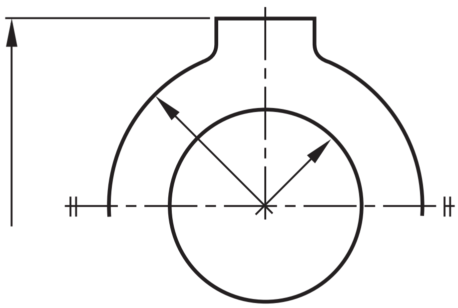


Figure 6 – Dimension lines on a partial view of a symmetrical part

1.5 Arrangement of dimensions

The way in which dimensions are typically used on drawings is shown in Figure 7. Conventions for arranging dimensions on drawings are as follows.

Dimensions shall be placed in the middle of the dimension line above and clear of it.

Dimensions shall not be crossed or separated by other lines on the drawing.

Values of angular dimensions shall be oriented so that they can be read from the bottom or the right-hand side of the drawing, as shown in Figure 8.

Where space is limited, the dimension can be placed centrally, above, or in line with, the extension of one of the dimension lines, as shown in Figure 9.

Larger dimensions shall be placed outside smaller dimensions, as shown in Figure 10.

Dimensions of diameters shall be placed on the view that provides the greatest clarity, as shown in Figure 11.

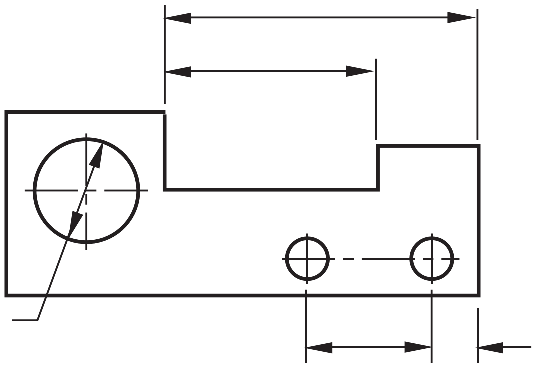


Figure 7 – Examples of the ways in which dimensions are typically used on drawings

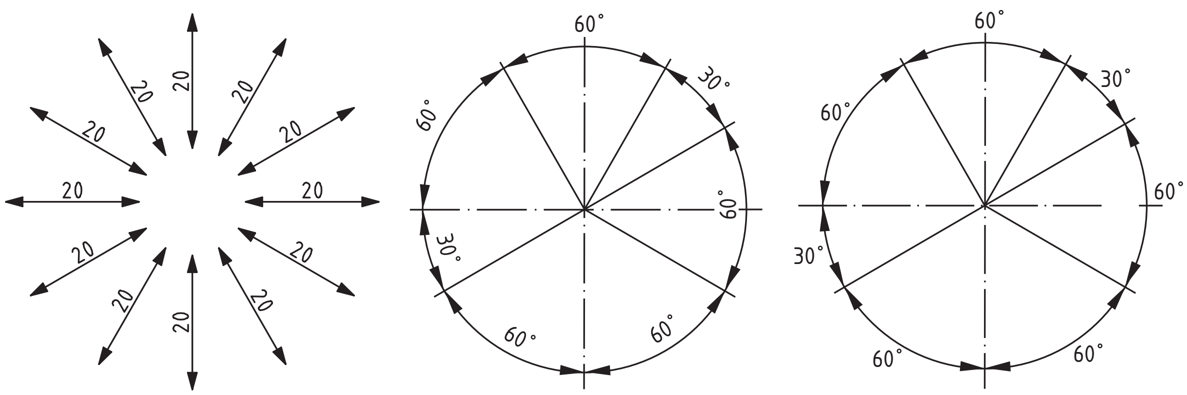


Figure 8 – Orientation of linear and angular dimensions

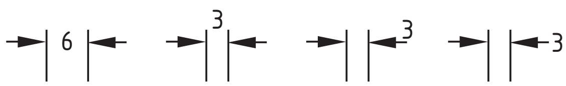


Figure 9 – Dimensioning smaller features

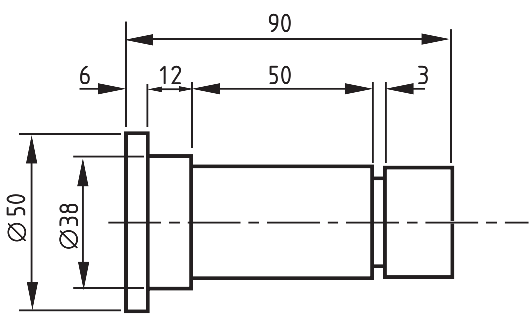


Figure 10 – Larger dimensions placed outside smaller dimensions

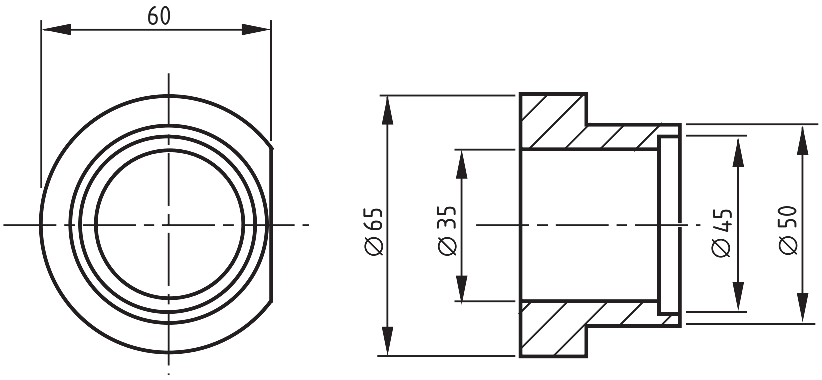


Figure 11 – Dimensions of diameters placed on view providing greatest clarity

Dimensioning from a common feature can be used where a number of dimensions of the same direction relate to a common origin.

Dimensioning from a common feature may be executed as parallel dimensioning or as superimposed running dimensioning.

Parallel dimensioning is the placement of a number of single dimension lines parallel to one another and spaced out so that the dimensional value can easily be added in, as shown in Figure 12a.

Superimposed running dimensioning is a simplified parallel dimensioning and may be used where there are space limitations. The common origin is as shown in Figure 12. Dimension values may be above and clear of the dimension line, as shown in Figure 12b; or in line with the corresponding extension line, as shown in Figure 12c.

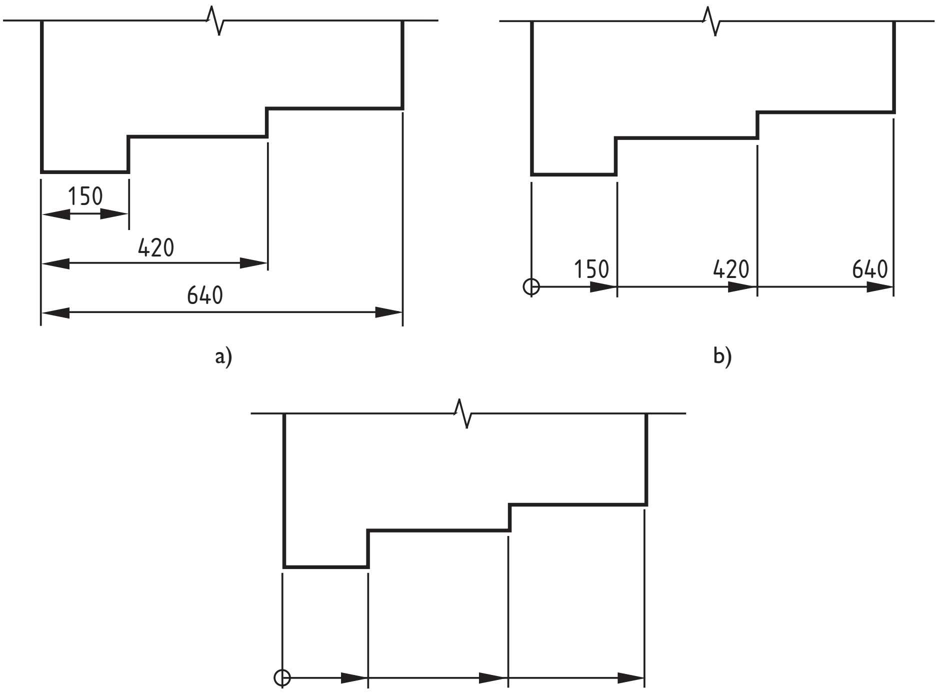


Figure 12 – Parallel dimensioning and running dimensioning

Chain dimensioning consists of a chain of dimensions. These shall only be used where the possible accumulation of tolerances does not affect the function of the part, as shown in Figure 13.

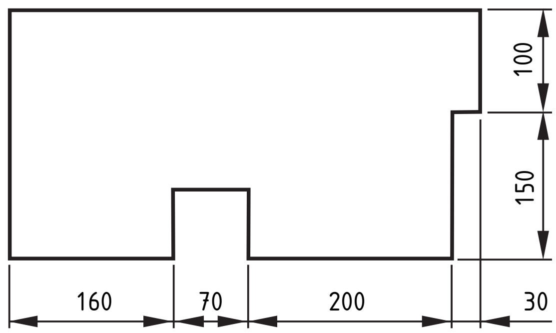
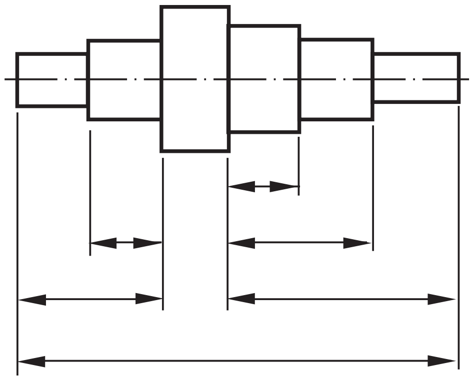
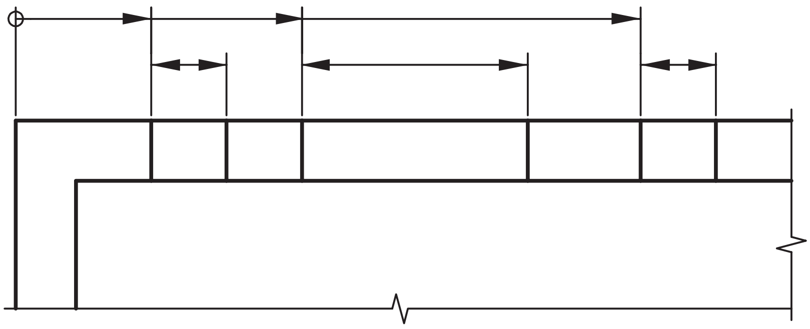


Figure 13 – Chain dimensioning

Combined dimensioning uses chain dimensioning and parallel dimensioning on the same drawing view. Figure 14a illustrates combining single dimensions and parallel dimensioning from a common feature. Figure 14b illustrates combining single dimensions and chain dimensions.



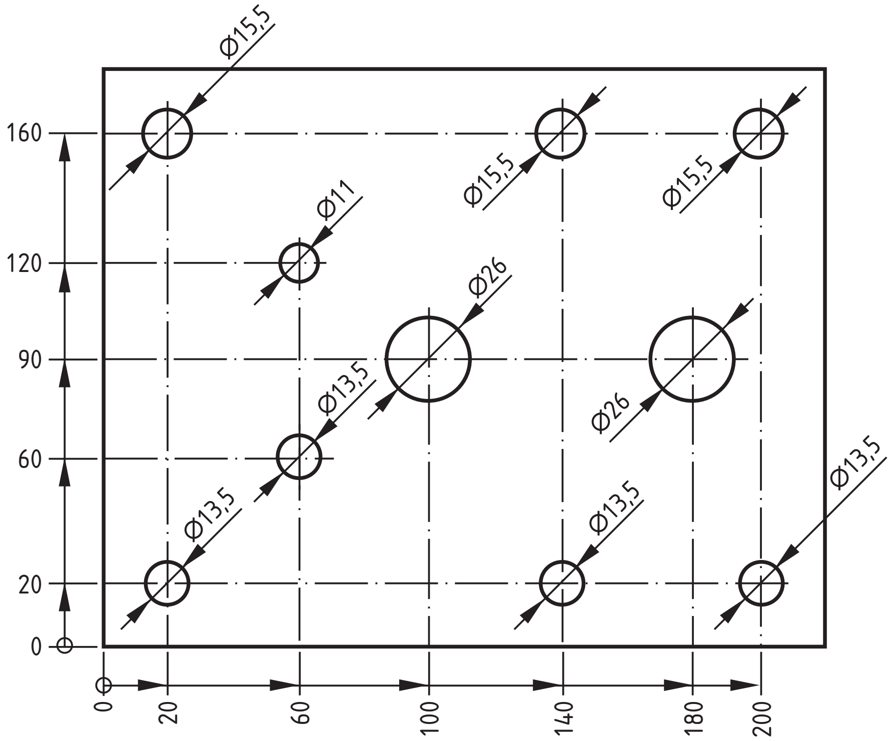
a)



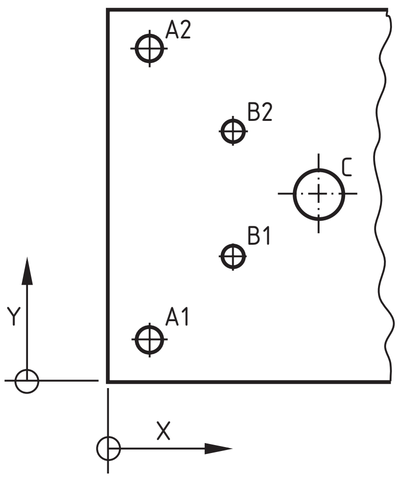
b)

Figure 14 – Combined dimensioning

Dimensioning by coordinates uses superimposed running dimensioning in two directions at right angles, as shown in Figure 15a. The common origin may be any suitable common reference feature. It may be useful, instead of dimensioning as shown in Figure 15a, to tabulate dimensional values as shown in Figure 15b.



a) in two directions



Hole	X	Y	Ø
A1	20	20	15
A2	20	160	15
B1	60	60	10
B2	60	120	10
C	100	90	25

b) tabulated

Figure 15 – Dimensioning by coordinates

1.6 Methods for dimensioning common features

Certain features, such as diameters, radii, squares, hole sizes, chamfers, countersinks and counter-bores, can occur frequently in engineering drawings.

A diameter of a circle or cylinder shall be dimensioned by prefixing the value with the symbol Ø, as shown in Figure 16. A square feature shall be dimensioned by prefixing the value with the symbol □. Additionally, square and flat features can be indicated by continuous narrow lines drawn diagonally on the flat feature, as shown in Figure 18.

Where dimension lines and other lines (e.g. extension lines) would otherwise intersect, the dimension lines to the feature can be dimensioned by leader lines as shown in Figure 16.

Where the whole view is not shown, concentric diameters shall be dimensioned as in Figure 17.

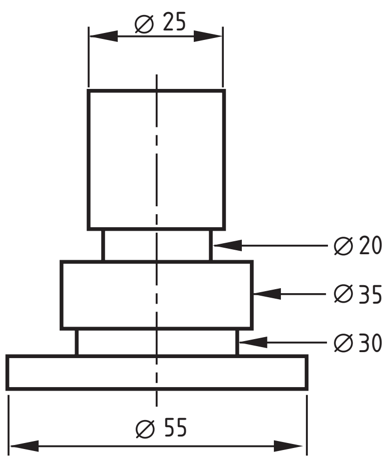


Figure 16 – Diameter dimensions indicated by leader lines

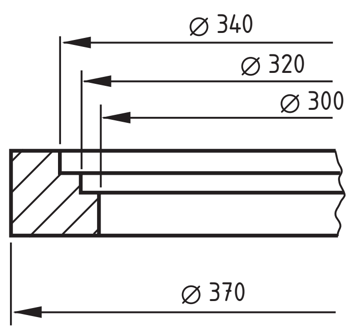


Figure 17 – Dimensioning concentric diameters on a partial view

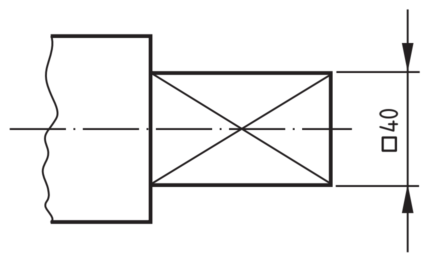


Figure 18 – Dimensioning a square

Circles shall be dimensioned as shown in Figure 19 and spherical surfaces as shown in Figure 20.

Radii of features shall be dimensioned by prefixing the value with the letter R. Radii shall be dimensioned by a line that passes through, or is in line with, the centre of the arc. The dimension line shall have one arrowhead only, which shall touch the arc.

Radii that require their centres to be located shall be dimensioned as in Figure 21a; those that do not shall be dimensioned as in Figure 21b. Spherical radii shall be dimensioned as shown in Figures 21c and 21d.

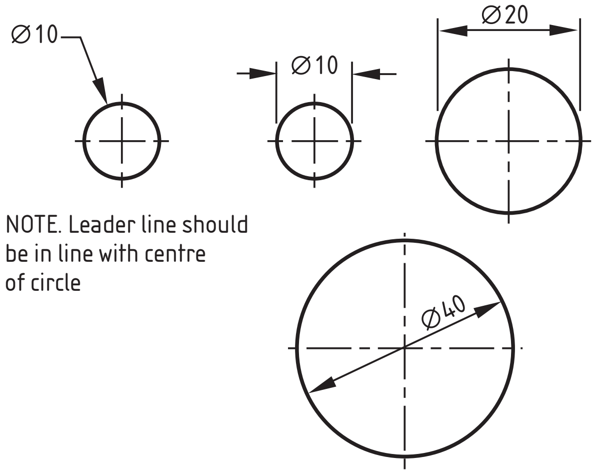


Figure 19 – Dimensioning a diameter

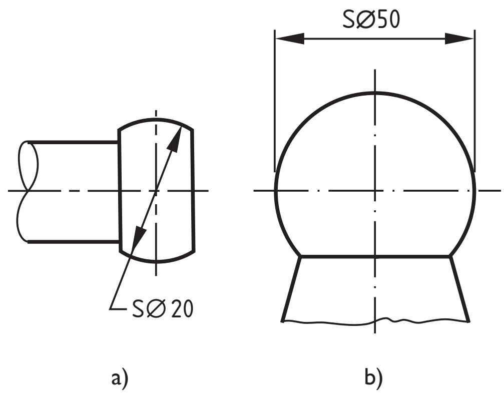


Figure 20 – Dimensioning spherical diameters

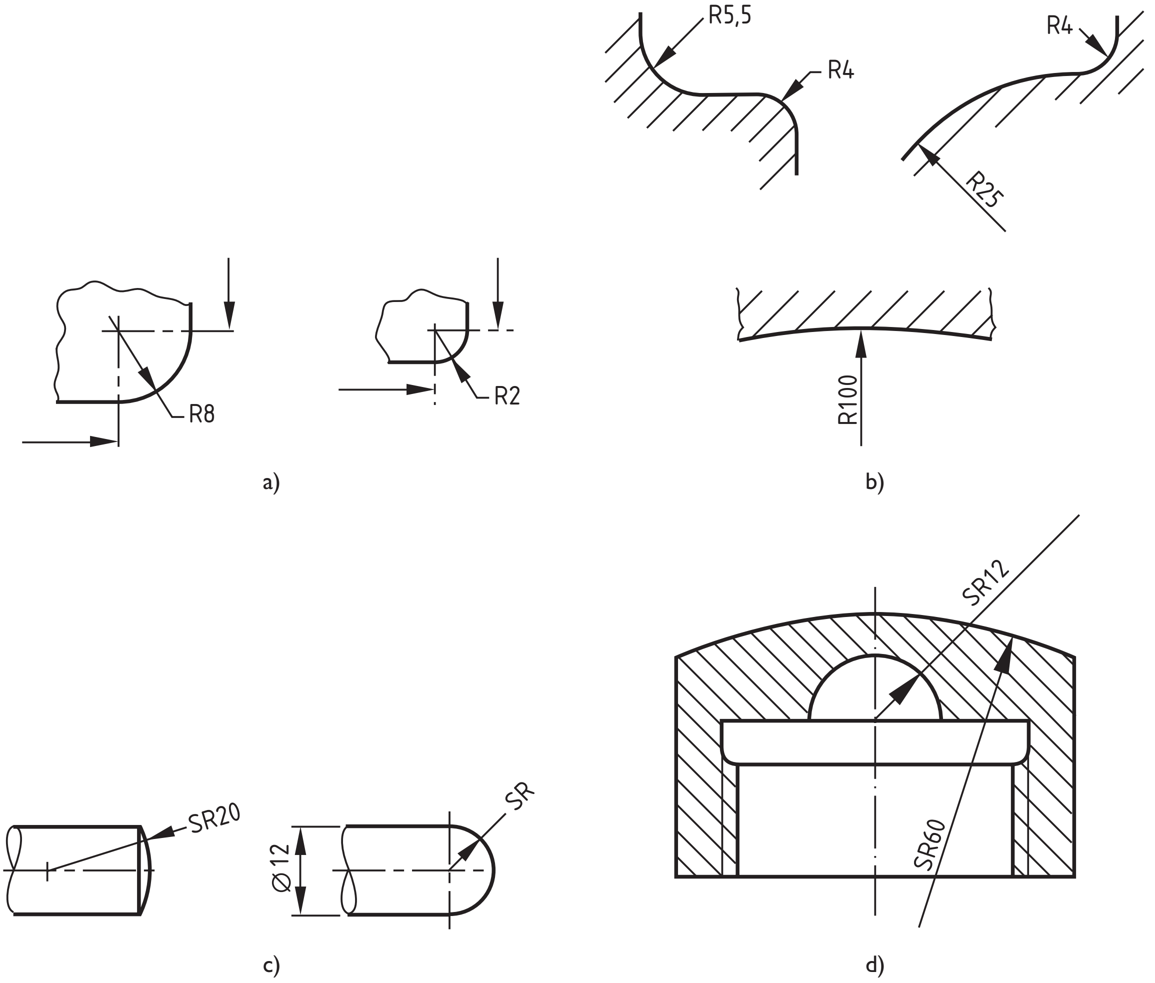


Figure 21 – Dimensioning radii

Holes shall be dimensioned as shown in Figure 22. The depth of the drilled hole, when given after the diameter, refers to the depth of the cylindrical portion of the hole and not to the extremity made by the point of the drill, unless otherwise specified.

The method of production (e.g. drill, punch, bore or ream) shall not be specified except where it is essential to the function of the part.

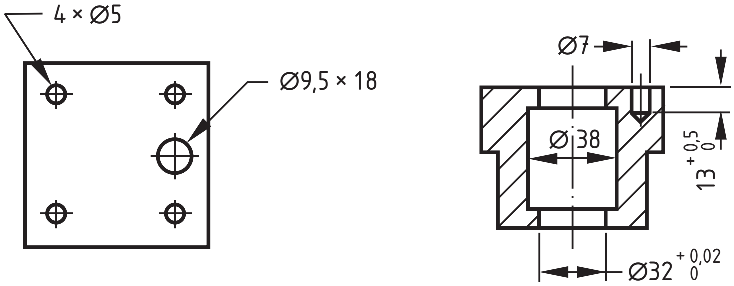


Figure 22 – Dimensioning holes

The dimensioning of chords, arcs and angles shall be as shown in Figure 23.

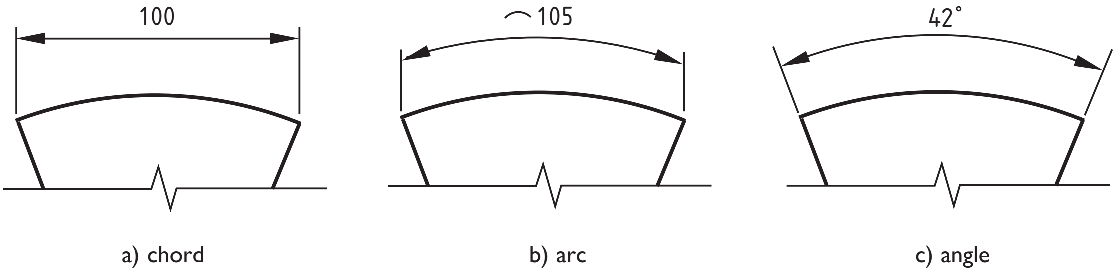


Figure 23 – Dimensioning chords, arcs and angles

Dimensioning the spacing of holes and other features on a curved surface shall be as shown in Figure 24, whether the dimensions are chordal or circumferential, they shall be indicated clearly on the drawing.

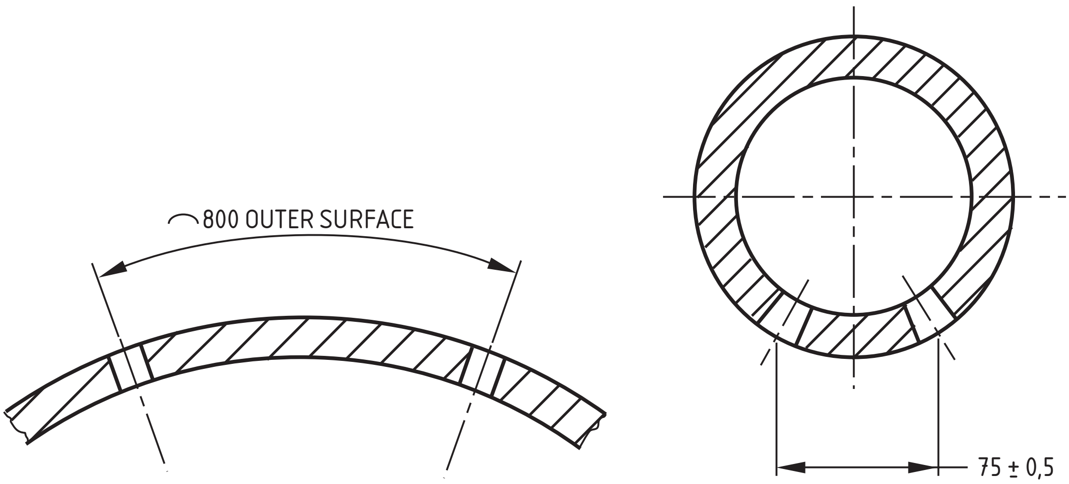


Figure 24 – Dimensions on a curved surface

1.7 Dimensioning screw threads and threaded parts

ISO metric screw threads shall be designated in accordance with BS EN ISO 6410-1, which specifies that the designation shall indicate the thread system, nominal diameter and the thread tolerance class. If necessary, the pitch shall also be indicated; however, when designating metric coarse threads, the pitch is generally omitted.

The nominal diameter refers to the major diameter of external and internal threads; the dimension relating to the depth of thread refers to the full depth of thread. The direction of a right hand thread (RH) is not generally noted; however left hand threads shall be denoted with the abbreviation 'LH' after the thread designation.

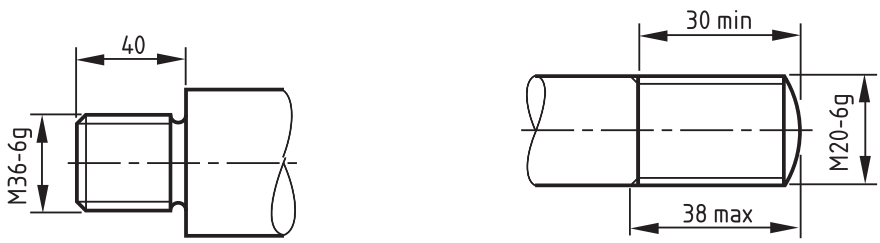
Thread system and size

The letter M, denoting ISO metric screw threads, shall be followed by the values of the nominal diameter and pitch (if required), with a multiplication sign between them, e.g. M8 × 1.

Thread tolerance class

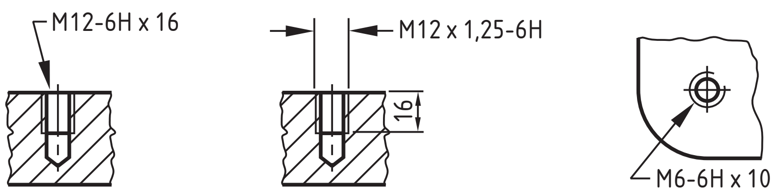
For general use, the tolerance class 6H is suitable for internal threads and tolerance class 6g for external threads. The thread tolerance class shall be preceded by a hyphen, e.g. M10-6H or M10 × 1-6g.

Screw threads shall be dimensioned as shown in Figures 25 and 26.



a) b)

Figure 25 – Dimensioning external screw threads



a) b) c)

Figure 26 – Dimensioning internal screw threads

1.8 Dimensioning chamfers and countersinks

Chamfers shall be dimensioned as shown in Figure 27. Where the chamfer angle is 45°, the indications may be simplified as shown in Figure 28.

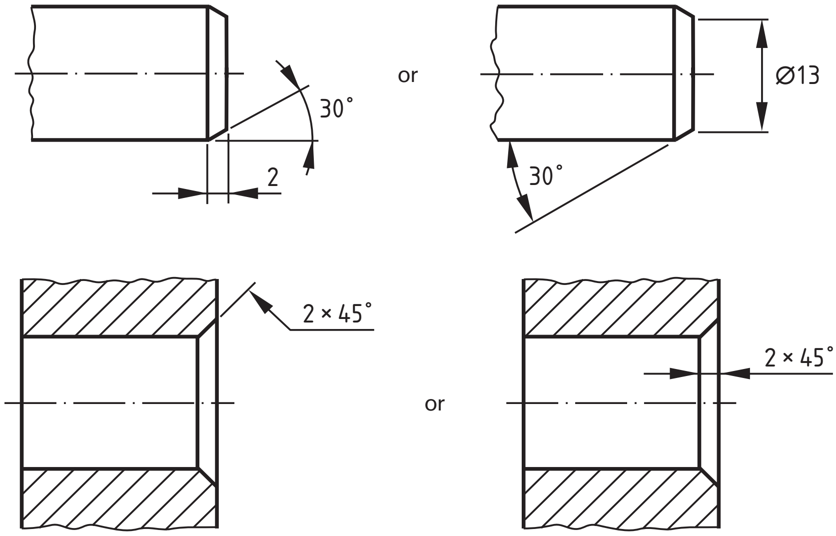


Figure 27 – Dimensioning external and internal chamfers

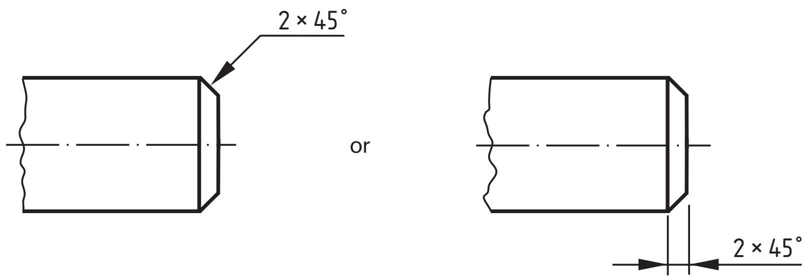


Figure 28 – Simplified dimensioning of chamfers

Countersinks shall be dimensioned by showing either the required diametral dimension at the included angle, or the depth and the included angle, as shown in Figure 29.

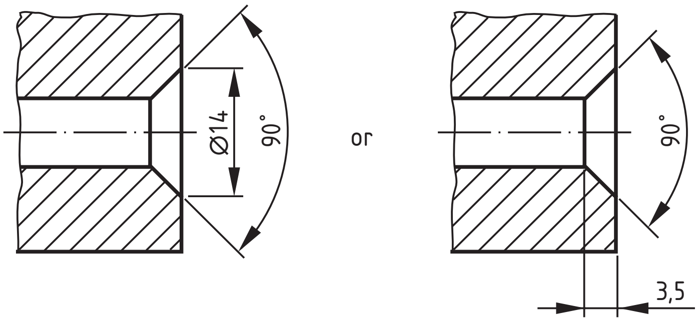


Figure 29 – Dimensioning countersinks

1.9 Equally spaced repeated features

Where repeated features are linearly spaced, a simplified method of dimensioning may be used, as shown in Figure 30.

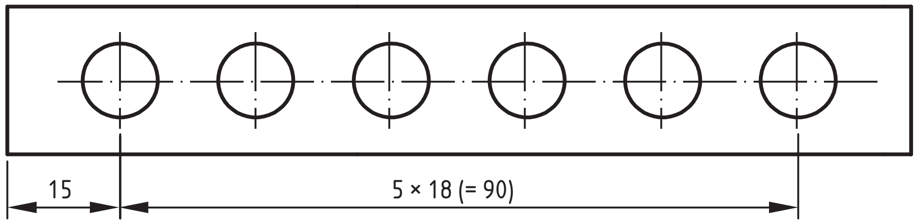


Figure 30 – Dimensioning of linear spacings

If there is any ambiguity, one feature space may be dimensioned as illustrated in Figure 31.

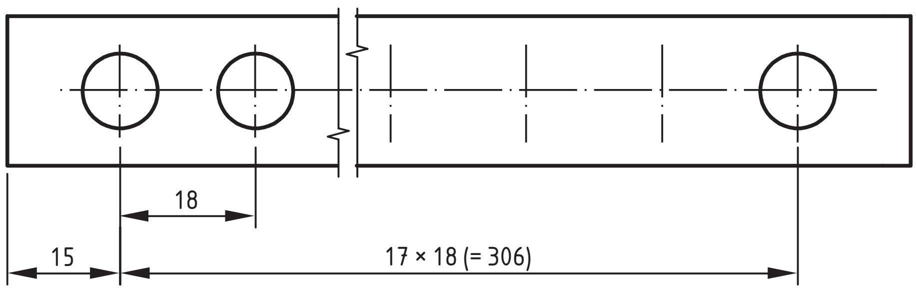


Figure 31 – Dimensioning of linear spacings to avoid confusion

Angular, equally spaced features shall be dimensioned as shown in Figure 32. The angle of the spacings can be omitted where the intent is explicit, as shown in Figure 33.

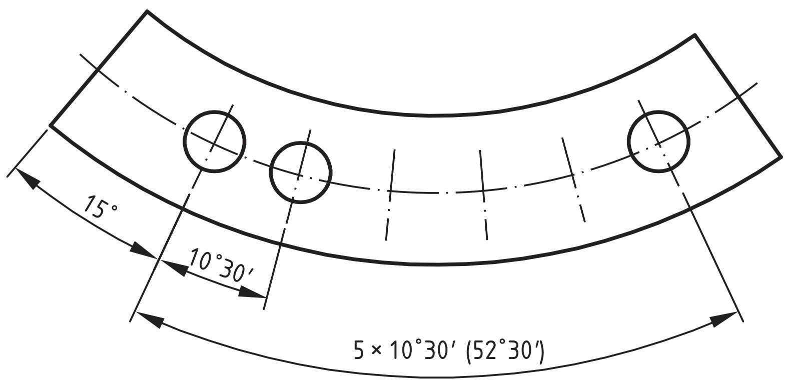


Figure 32 – Dimensioning angular spacing

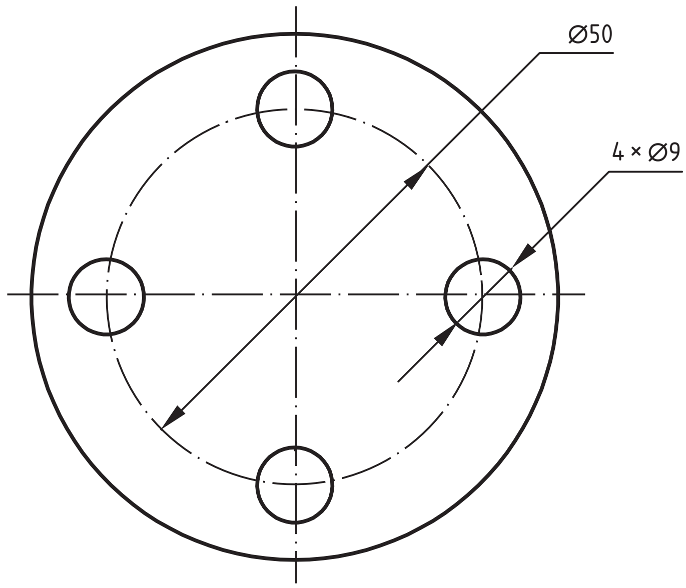


Figure 33 – Omission of angle of spacing

Circular spaced features can be dimensioned indirectly by specifying the number of common features as shown in Figure 34.

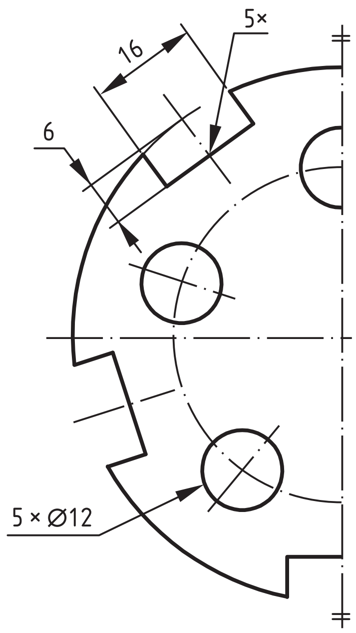


Figure 34 – Dimensioning circular spacings

Series or patterned features of the same size may be dimensioned as illustrated in Figures 35 and 36.

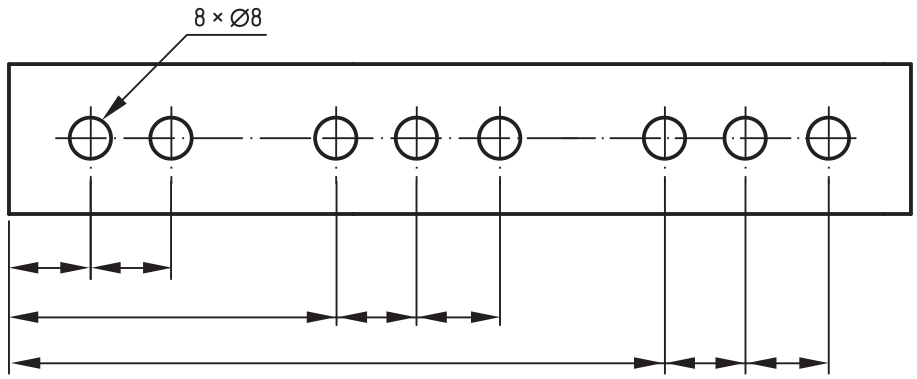


Figure 35 – Dimensioning a quantity of features of the same size – linear

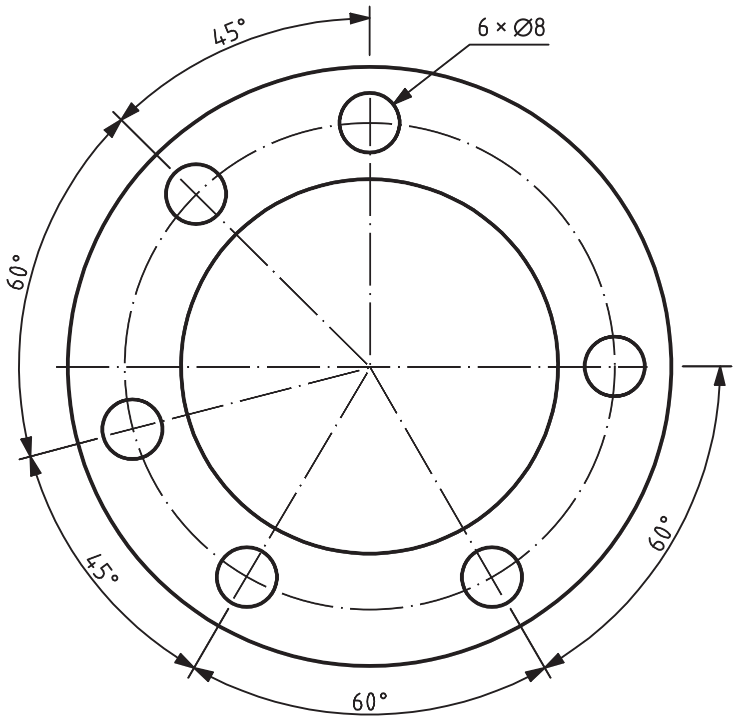


Figure 36 – Dimensioning a quantity of features of the same size – circular

1.10 Dimensioning of curved profiles

Curved profiles composed of circular arcs shall be dimensioned by radii, as shown in Figure 37.

Coordinates locating points on a curved surface, as shown in Figure 38, shall only be used when the profile is not composed of circular arcs. The more coordinates specified, the better the uniformity of the curve.

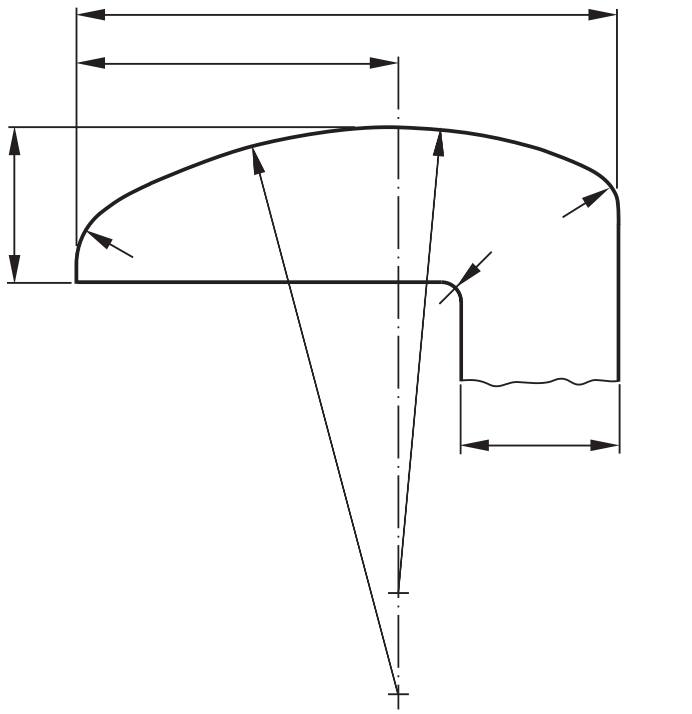


Figure 37 – Dimensioning of a curved profile

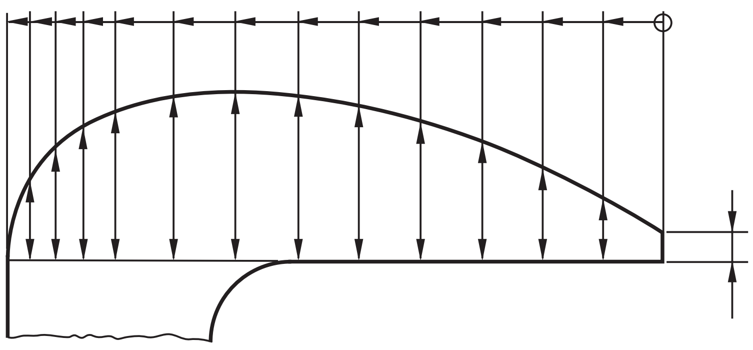


Figure 38 – Linear coordinates of a series of points through which a profile passes

1.11 Dimensioning of keyways

Keyways in hubs or shafts shall be dimensioned by one of the methods shown in Figure 39.

NOTE: Further information on keys and keyways is given in BS 4235-1, *Specification for metric keys and keyways – Part 1: Parallel and taper keys* and BS 4235-2, *Specification for metric keys and keyways – Part 2: Woodruff keys and keyways*.

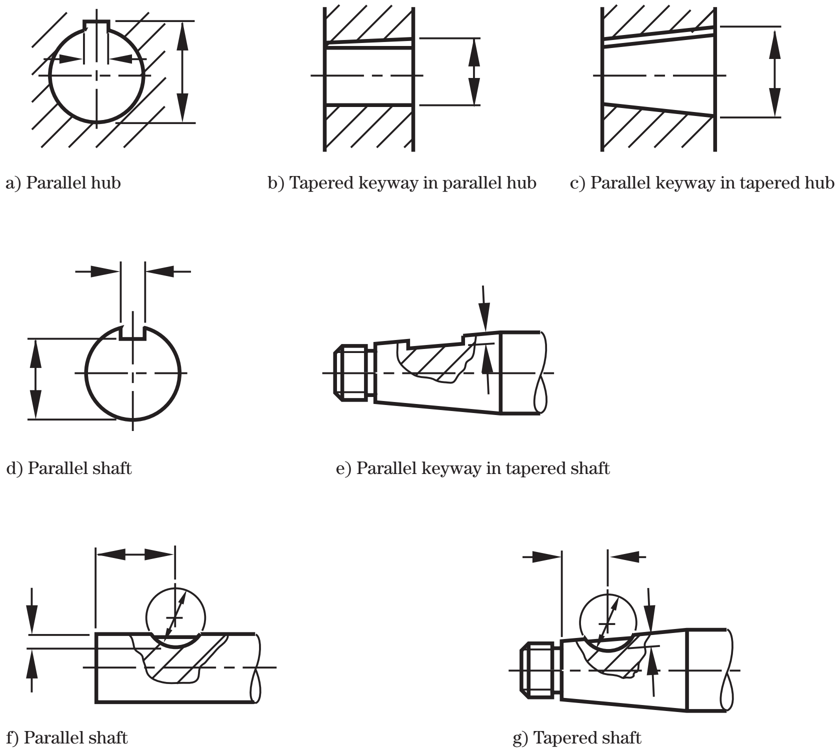


Figure 39 – Dimensioning of keyways

1.12 Tolerancing

Tolerancing is the practice of specifying the upper and lower limit for any permissible variation in the finished manufactured size of a feature. The difference between these limits is known as the tolerance for that dimension.

All dimensions (except auxiliary dimensions) are subject to tolerances.

Tolerances shall be specified for all dimensions that affect the functioning or interchange ability of the part.

Tolerances shall also be used to indicate where unusually wide variations are permissible.

Tolerances shall be applied either to individual dimensions or by a general note giving uniform or graded tolerances to classes of dimensions, for example:

TOLERANCE UNLESS OTHERWISE STATED LINEAR ±0,4 ANGULAR ±0° 30′

The method shown in Figure 40a should be followed where it is required to tolerance individual linear dimensions. This method directly specifies both the limits of the size of the dimension, the tolerance being the difference between the limits of the size.

The larger limit of the size shall be placed above the smaller limit and both shall be given to the same number of decimal places.

The method shown in Figure 40b can be used as an alternative way of specifying tolerances.

Figure 40 – Linear dimension tolerance by directly specifying limits of size

The methods shown in Figure 41 may be used to tolerance individual angular dimensions.

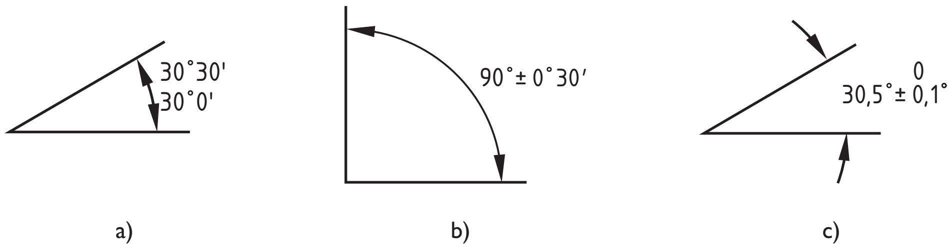


Figure 41 – Tolerancing angular dimensions

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

Limits of size for an individual feature-of-size shall be interpreted according to the principles and rules defined in BS ISO 8015, BS EN ISO 14660-1 and BS EN ISO 14660-2.

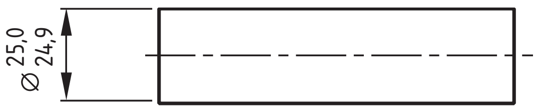
A feature-of-size may consist of two parallel plane surfaces, a cylindrical surface or a spherical surface, in each case defined with a linear size. A feature-of-size may also consist of two plane surfaces at an angle to each other (a wedge) or a conical surface, in each case defined with an angular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

BS ISO 8015 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 may 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 ISO 8015).

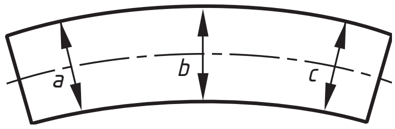
BS ISO 8015 defines the principle of independency, according to which each specified dimensional and geometrical requirement on a drawing is met independently, unless a particular relationship is specified. A relationship may be specified through the use of the envelope requirement or material condition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

Where no relationship is specified, any geometrical tolerance applied to the feature-of-size applies regardless of feature size, and the two requirements shall be treated as unrelated, as shown in Figure 42. 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 needs to be specified.

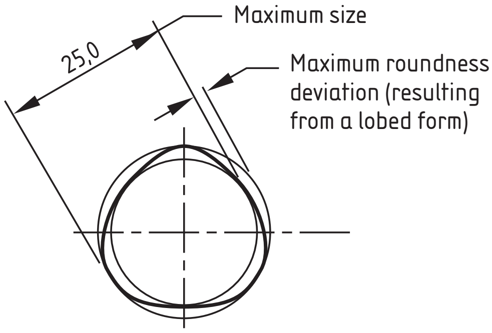


a) Drawing presentation



NOTE There is no form control (i.e. over roundness, straightness or cylindricity). Measurements a, b and c may lie between 25.0 mm and 24.9 mm, meeting the drawing requirement using two-point measurement only.

b) Permissible interpretation: straightness unconstrained



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

c) Permissible interpretation: roundness unconstrained

Figure 42 – Permissible interpretations when no form control is given on the drawing

1.13.1 Limits of size with mutual dependency of size and form

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.

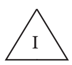
Standards which apply, or have applied, the envelope requirement by default include:

ASME Y14.5

The requirement that there shall be an envelope of perfect form corresponding to the maximum material size of the feature is defined as Rule #1).

BS 308

The principle of dependency was taken as the default option under BS 308, although the option of working to the principle of independency was included, through the use of the BS 308 triangle I indication.

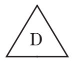


BS 8888

Prior to the 2004 revision; the principle of dependency was taken as the default option under BS 8888:2000 and BS 8888:2002, although the option of working to the principle of independency was included, through the use of the BS 8888 triangle I indication.

BS 8888:2004 and BS 8888:2006

the principle of dependency could be explicitly invoked through the use of the BS 8888 triangle D indication.



As the interaction between the envelope requirement and individual geometrical tolerances is not always fully defined within the ISO system, and as the application of the envelope requirement by default to all features-of-size is not formally supported within the ISO system, the use of the principle of dependency is no longer recommended.

1.14 Datum surfaces and functional requirements

Functional dimensions shall be expressed directly on the drawing, as shown in Figure 1. The application of this principle will result in the selection of reference features on the basis of the function of the product and the method of locating it in any assembly of which it may form a part.

If any reference feature other than one based on the function of the product is used, finer tolerances will be necessary to meet the functional requirement, which in turn will increase the cost of producing the product, as shown in Figure 43 on page 22.

1.15 Relevant standards

BS EN ISO 1660, *Technical drawings — Dimensioning and tolerancing of profiles*
BS ISO 129-1, *Technical drawings — Indication of dimensions and tolerances — Part 1: General principles*
BS ISO 3040, *Technical drawings — Dimensioning and tolerancing — Cones*
BS ISO 10579, *Technical drawings — Dimensioning and tolerancing — Non-rigid parts*
BS ISO 406, *Technical drawings — Tolerancing of linear and angular dimensions*
BS EN 22768-1, *General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*
BS 4235-1, *Specification for metric keys and keyways — Part 1: Parallel and taper keys*
BS 4235-2, *Specification for metric keys and keyways — Part 2: Woodruff keys and keyways*
BS ISO 8015, *Technical drawings — Fundamental tolerancing principle*
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*
PP 8888-2, *Engineering drawing practice: a guide for further and higher education to BS 8888:2006, Technical product specification (TPS)*

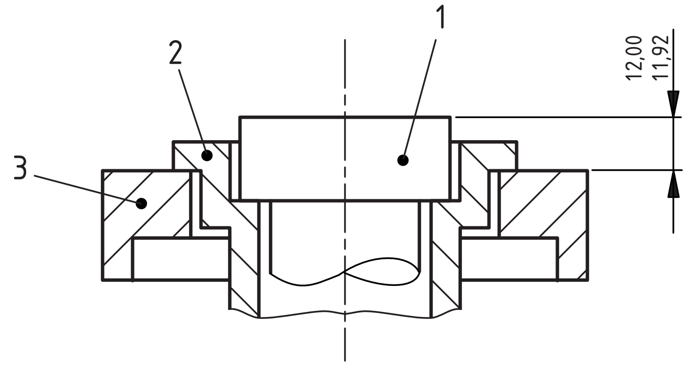
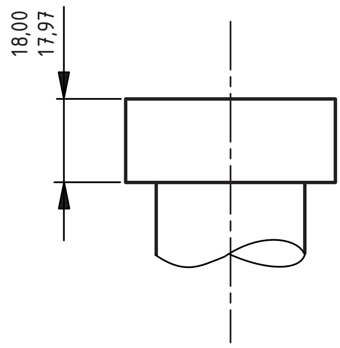
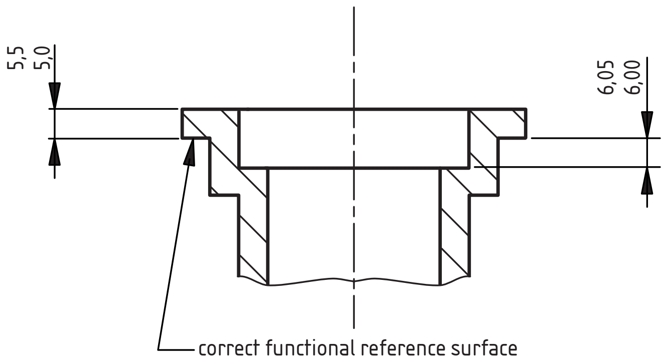
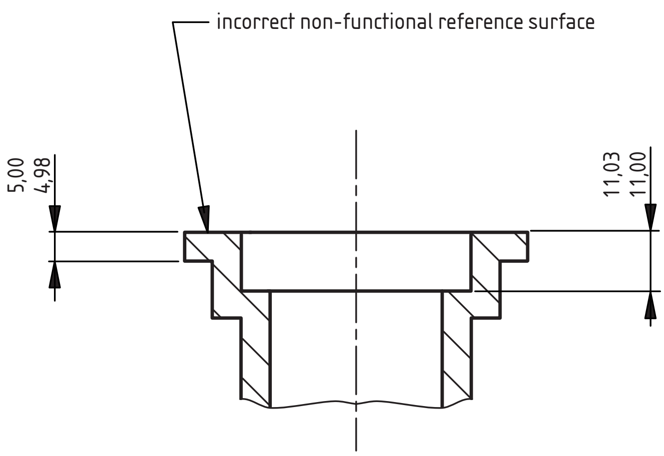
Description	**Drawing**
a) Assembly drawing showing a given functional requirement, namely the limits of height of the top face of item 1 above the top face of item 3, with a tolerance of 0.08 mm	
b) Detail of head of item 1 showing given limits of size, with a tolerance of 0.03 mm	
c) Item 2 dimensioned from a functional reference surface NOTE: One direct dimension with a tolerance of 0.05 mm is needed to satisfy the condition shown in a). A nominal flange thickness of 5 mm has been assumed. This value is non-functional and can have any large tolerance.	
d) Item 2 dimensioned from a non-functional reference surface NOTE: Tolerances have had to be reduced; two dimensions with tolerances of, say, 0.02 mm for the flange and 0.03 mm are now needed to satisfy the condition shown in a).	

Figure 43 – Effect on tolerances by changing datum surfaces from those determined by functional requirements