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SOUTH AFRICAN NATIONAL STANDARD

Engineering drawings

Amdt 2

Part 1: General principles

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SABS

Contents

Engineering drawings

Amdt 2

Part 1:
General principles

1 Scope

1.1 This part of SANS 10111 covers the general principles of mechanical engineering drawing and includes the preparation, dimensioning and tolerancing of drawings of mechanical parts used in the fields of mechanical, civil and electrical engineering.

1.2 This part of the code does not include geometric tolerancing.

NOTES

a) The figures given in this part of the code are complete only in so far as is necessary to illustrate the point under consideration, and are not intended to be fully dimensioned working drawings.

b) Except where otherwise specified, all dimensions on drawings are in millimetres.

c) The standards referred to in this part of the code are listed in appendix A.

d) Recommended abbreviations and symbols are given in appendix B.

2 Drawing sheets and materials

2.1 Sizes

a) Drawing sheets should be of one of the sizes given in table 1. Drawing sheets of lengths exceeding 1 189 mm may be used in exceptional circumstances.

b) The smallest of the recommended sizes that is consistent with clarity should be used wherever possible.

2.2 Layout of information

2.2.1 General

The layout of drawing sheets with regard to title blocks, parts lists, etc., and the printing style should be decided by each organization to suit its specific requirements. Pre-printing of drawing and tracing sheets should be done on the front face to avoid loss of definition in microfilms.

2.2.2 Camera alignment marks

In the border at the midpoint of each of the four border lines of the drawing, a camera alignment mark (centring mark) should be drawn in the form of an arrow or a thick line of length equal to the width of the border (see figure 1).

Table 1 — Size of drawing sheets: ISO A series*

1	2	3
Designation	**Dimensions+** mm	**Width of border** mm
A0	841 × 1 189	20
A1	594 × 841	20
A2	420 × 594	15
A3	297 × 420	15
A4	210 × 297	15

* See ISO 216.
\+ The permissible tolerances on these sizes are ± 2 mm for dimensions not exceeding 600 mm, and ± 3 mm for dimensions exceeding 600 mm.

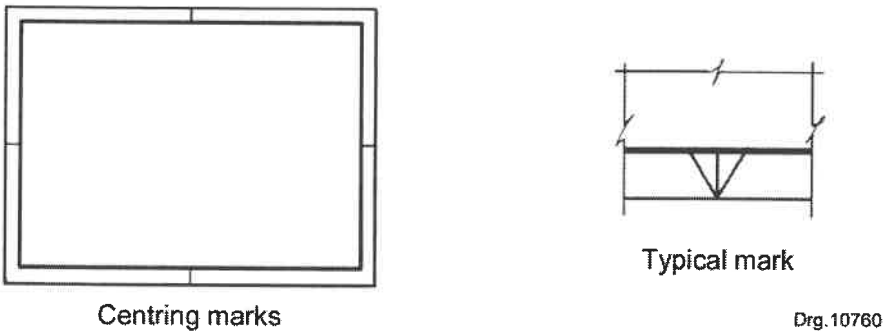


Figure 1 — Camera alignment marks

2.3 Drawing number

2.3.1 General

The drawing number should be placed in bold legible characters of height at least equal to the appropriate value given in tables 4 and 5, in the bottom right-hand corner and, when so required, in the most suitable position at the top of the sheet, above the drawing.

2.3.2 Revisions

All revised drawings should be marked with a revision character in the appropriate space in the title block.

2.4 Drawing materials

2.4.1 Choice of materials

Materials that provide the maximum contrast between characters and drawing sheet should be used.

2.4.2 Pencil

Only pencils that will cause neither indentation nor smudging on the drawing sheet should be used. Plastics-film leads are recommended for use on film, but these leads should not be used on ordinary paper.

2.4.3 Ink

A black ink that dries to a matt finish (to avoid reflection in the lens of a copy camera) should be used.

2.4.4 Drawing sheets

A drawing material that has a non-reflecting surface should be used.

3 Scales

3.1 Scales for preparing drawings

Drawings should be prepared to an appropriate scale, preferably one of those given in table 2. The scale used should be clearly indicated on the drawing.

NOTE If, for a special application, there is a need for a larger enlargement scale or a smaller reduction scale than those shown in the table, the recommended range of scales may be extended in either direction, provided that the required scale be derived from a recommended scale by multiplying by a multiple of 10. In exceptional cases where, for functional reasons, the recommended scales cannot be applied, intermediate scales may be chosen.

Table 2 — Scales for preparing drawings

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

3.2 Metric reference scale[1)]

All original drawings should be marked with a metric reference scale at the bottom of the drawing and preferably placed symmetrically about a centring mark near the frame in the border. The scale should be 100 mm long, with a maximum width of 5 mm, and marked off in units of 10 mm (see figure 2).

1) The metric reference scale will serve to indicate on microfilm copies the size of the original drawing.

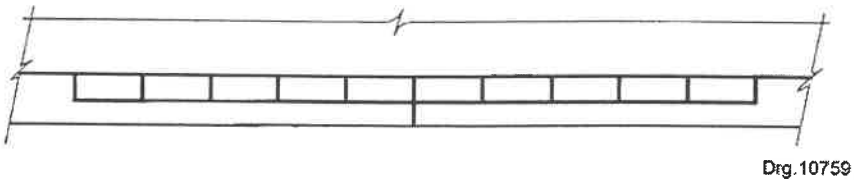


Figure 2 — Metric reference scale

4 Lines, letters, figures and symbols, and arrowheads

4.1 Lines

4.1.1 Quality of lines

a) All lines should be black, uniform and bold.

b) All the lines on a drawing, including those added in any revision, should be of consistent density and reflectance.

c) The lines on any one finished drawing sheet should be entirely in pencil or entirely in ink.

d) Each type of line should be of consistent thickness (see 4.1.2(c)).

4.1.2 Types of lines, their application, construction and precedence

a) **Types of lines and applications**. The various types of lines given in column 1 of table 3 should be used for the relevant applications given in column 3. (See figures 3 to 6 for examples of use of the different types of lines.)

b) **Special lines**. In cases where other types of lines are used in specialized fields (e.g. electrical or pipework diagrams), the conventions adopted should be clearly indicated on the drawing, by reference to the standard(s) in which they are described or by notes.

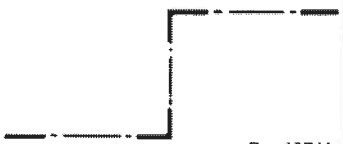
c) **Line thickness**. In general, no more than two thicknesses of lines should be used on one drawing; however, for lines that do not represent a real feature, it is preferable to use two thicknesses of those lines described in table 3 as "thin", (i.e. the thinner line for centre lines and dimension lines, and the thicker line for certain physical features, e.g. hidden detail, outlines of revolved sections, etc.). Where it is possible to restrict the drawing to two line thicknesses, the ratio of thickness should be approximately 2:1.

Line thicknesses should be chosen from the following range, according to the size and the type of drawing:

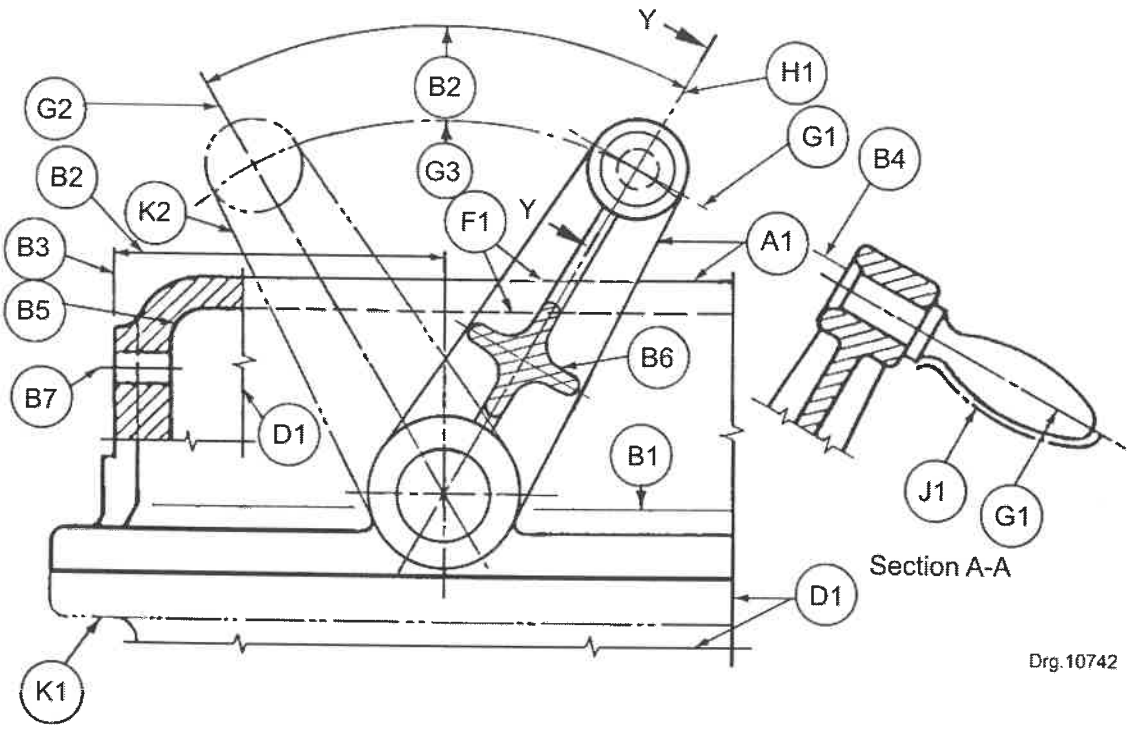
1) For ink drawings: 0,18 mm; 0,25 mm; 0,35 mm; 0,5 mm; 0,7 mm; 1 mm; 1,4 mm; and 2 mm;

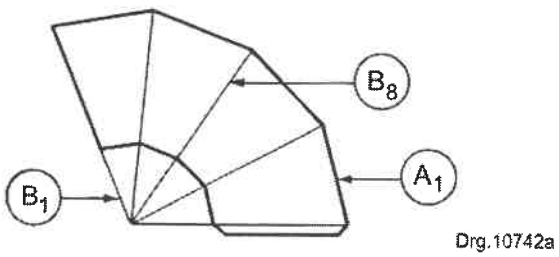
2) for pencil drawings: 0,3 mm; 0,5 mm; 0,7 mm; and 0,9 mm.

Table 3 — Types of lines

1	2	3
Line	**Description**	**General applications**
A Drg.10741	Continuous thick	A1 Visible outlines A2 Visible edges
B Drg.10741a	Continuous thin (Straight or curved)	B1 Imaginary lines of intersection B2 Dimensions lines B3 Projection lines B4 Leader lines B5 Hatching B6 Outlines of revolved sections in place B7 Short centre lines B8 Bending lines
C D*  Drg.10741b	Continuous thin freehand+ Continuous thin (straight) with zigzags	C1 Limits of partial or interrupted views and sections, if the limit is not a chain thin D1 Break line
E F Drg.10741c	Dashed thick+ Dashed thin	E1 Hidden outlines E2 Hidden edges F1 Hidden outlines F2 Hidden edges
G Drg.10741d	Chain thin	G1 Centre lines G2 Lines of symmetry G3 Trajectories
H  Drg.10741e	Chain thin, thick at ends and changes of direction	H1 Cutting planes
J Drg.10741f	Chain thick	J1 Indication of lines or surfaces to which a special requirement applies
K Drg.10741g	Chain thin double-dashed	K1 Outlines of adjacent components K2 Alternative and extreme positions of movable components K3 Centroidal lines K4 Initial outlines prior to forming K5 Parts situated in front of the cutting plane

* This type of line is suited for production of drawings by machines.
\+ Although two alternatives are available, it is recommended that on any one drawing, only one type of line be used.





Developed view to show blank shape

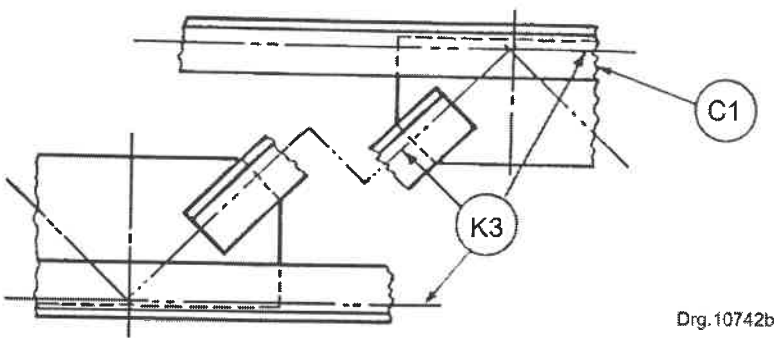


Figure 3 — Examples of use of some types of lines

d) **Line spacing**. To allow for the present limitations of printing and viewing of reduced microfilm copies, adjacent parallel lines should be spaced at least 1 mm apart. (It is accepted that in some cases the scale of the drawing will thus be violated.)

e) **Construction of type F, G, J and K lines** (see table 3)

1) **Type F lines**. As a general rule, the dashes and spaces should be approximately 3 mm and 2 mm long, respectively, but longer dashes and spaces may be used on larger drawings, provided the proportions are maintained. Except when a dash would form a continuation of a visible detail line, a type F line should begin and end with a dash in contact with the lines at which it starts and ends. Dashes at corners should be joined (see figure 4).

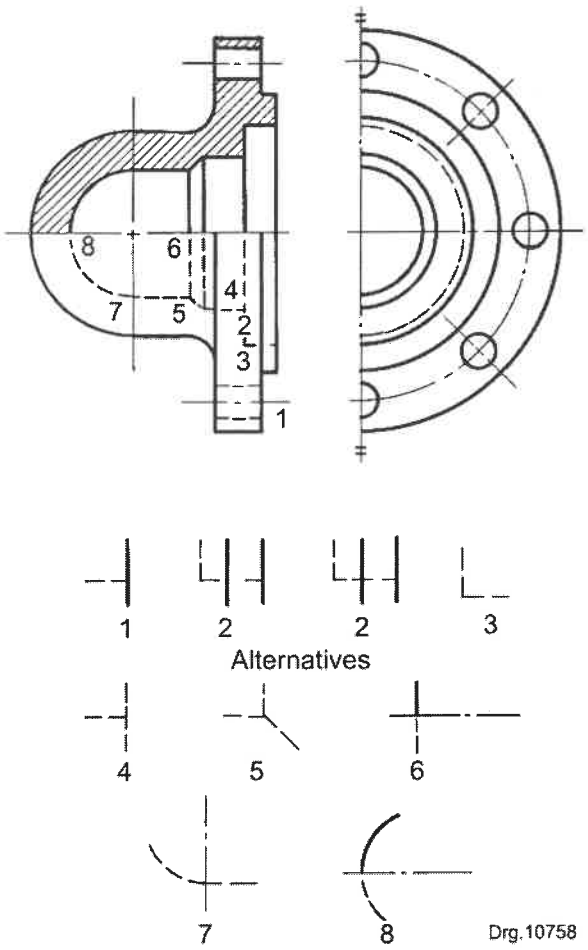
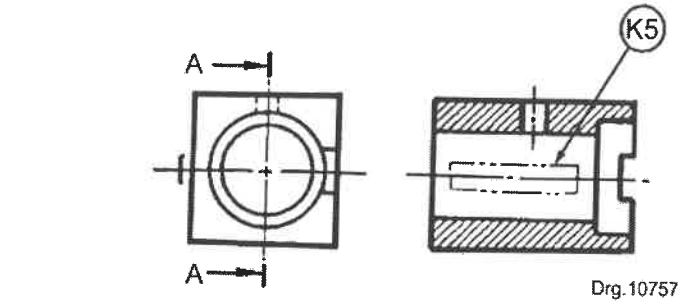


Figure 4 — Type F line — Examples of use and construction

2) **Type G, J and K lines**. The long dashes should be between 5 mm and 40 mm long (depending on the size of the detail) and the short dashes and the spaces approximately 2 mm long.

The centre lines should be extended a short distance beyond the relevant outlines and may also be extended for their dimensioning. Centre lines that intersect should cross on the long or short dashes and not in the spaces (see figures 5 and 6).



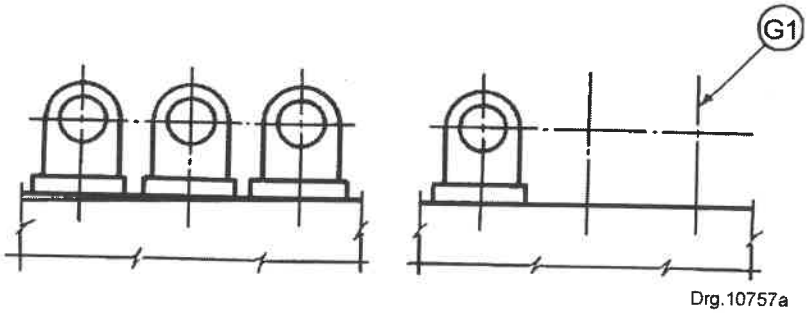
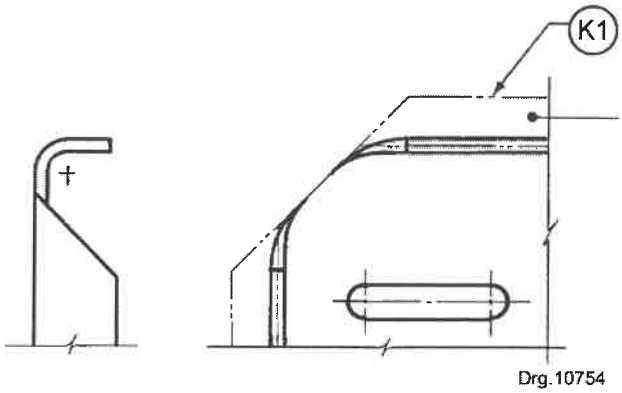
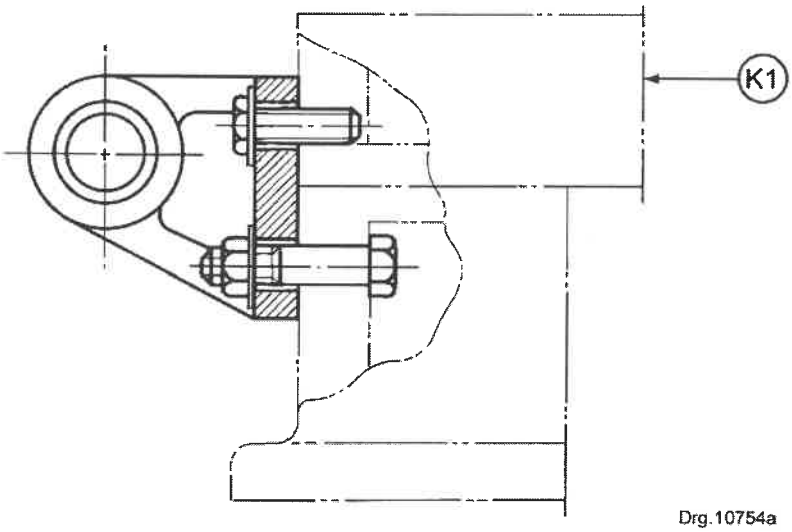


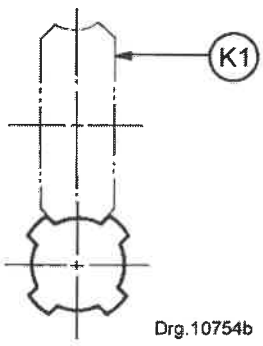
Figure 5 — Type G and type K lines — Examples of use and construction



(a) Developed view showing shape of blank superimposed



(b) Adjacent components



(c) Outline of tool

Figure 6 — Uses of type K line

f) **Precedence of lines**. In any view, different lines are likely to coincide. The outlines of hidden features of the component may coincide with those of visible features, or a centre line may coincide with a visible or hidden outline.

Because the physical features of the component have to be represented, full and dashed lines take precedence over all other lines. Since the visible outline is represented by full lines, these take precedence over dashed lines.

When a centre line and a cutting-plane line coincide, the one that is more important for the readability of the drawing takes precedence over the other.

Break lines (i.e. type D lines) should be so positioned that they do not spoil the readability of the overall view.

Dimension and projection lines should be so placed that they do not coincide with other lines of the drawing. The following list gives the order of precedence of lines:

1) full lines;

2) dashed lines;

3) centre lines or cutting-plane lines;

4) break lines;

5) dimension and projection lines;

6) hatch lines.

4.2 Letters, figures and symbols

4.2.1 General

The essential requirements for lettering on engineering drawings are

a) legibility,

b) uniformity, and

c) suitability for microfilming, and photographic and other types of reproduction.

4.2.2 Rules

In order to ensure that these requirements are met, the following rules should be observed:

a) Characters should be clear and of uniform size and density and clearly distinguishable from one another in order to avoid any confusion between them.

NOTE The following characters can easily be confused when badly formed or wrongly placed:

1) B, 8 and 3
2) 6 and 9
3) D and O
4) 3 and 5
5) C and G
6) 0 and Q
7) 5 and S
8) 2 and Z

b) The same style, spacing and size of letters and figures (except for providing emphasis, as recommended in 5.5) should be used in each note on a drawing.

c) In a drawing that may be used for microfilming, and for photographic and other types of reproduction, the space between characters should be at least twice the line thickness (see figure 9 and table 5).

d) The line thickness for lower-case and capital letters should be the same in order to facilitate lettering.

e) Capital letters should be used in preference to lower-case letters, since they are less congested and are less likely to be misread when reduced in size.

NOTE Lower-case letters should be used where they form part of a standard symbol, code or abbreviation.

f) Lettering should be either vertical (upright) or inclined up to 15° to the right.

Examples of acceptable types of letters, figures and symbols are given in figures 7 and 8.

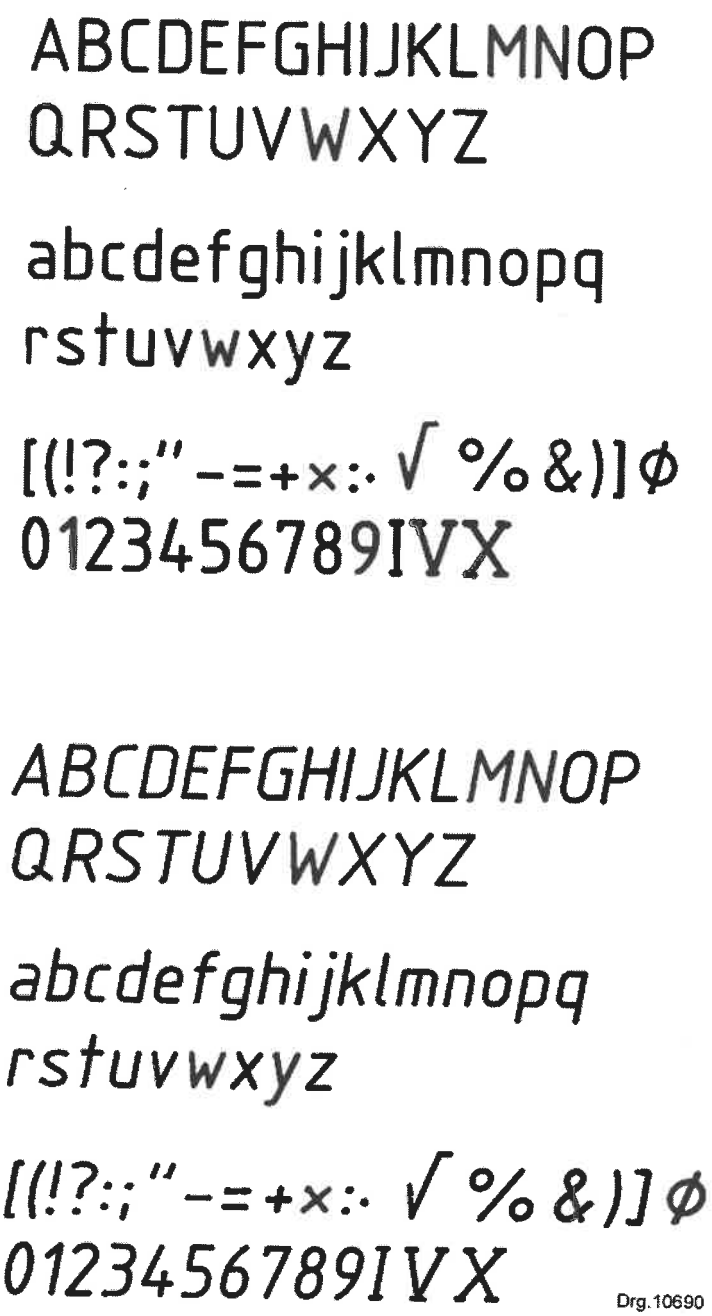


Figure 7 — Acceptable types of letters, figures and symbols (ISO origin)

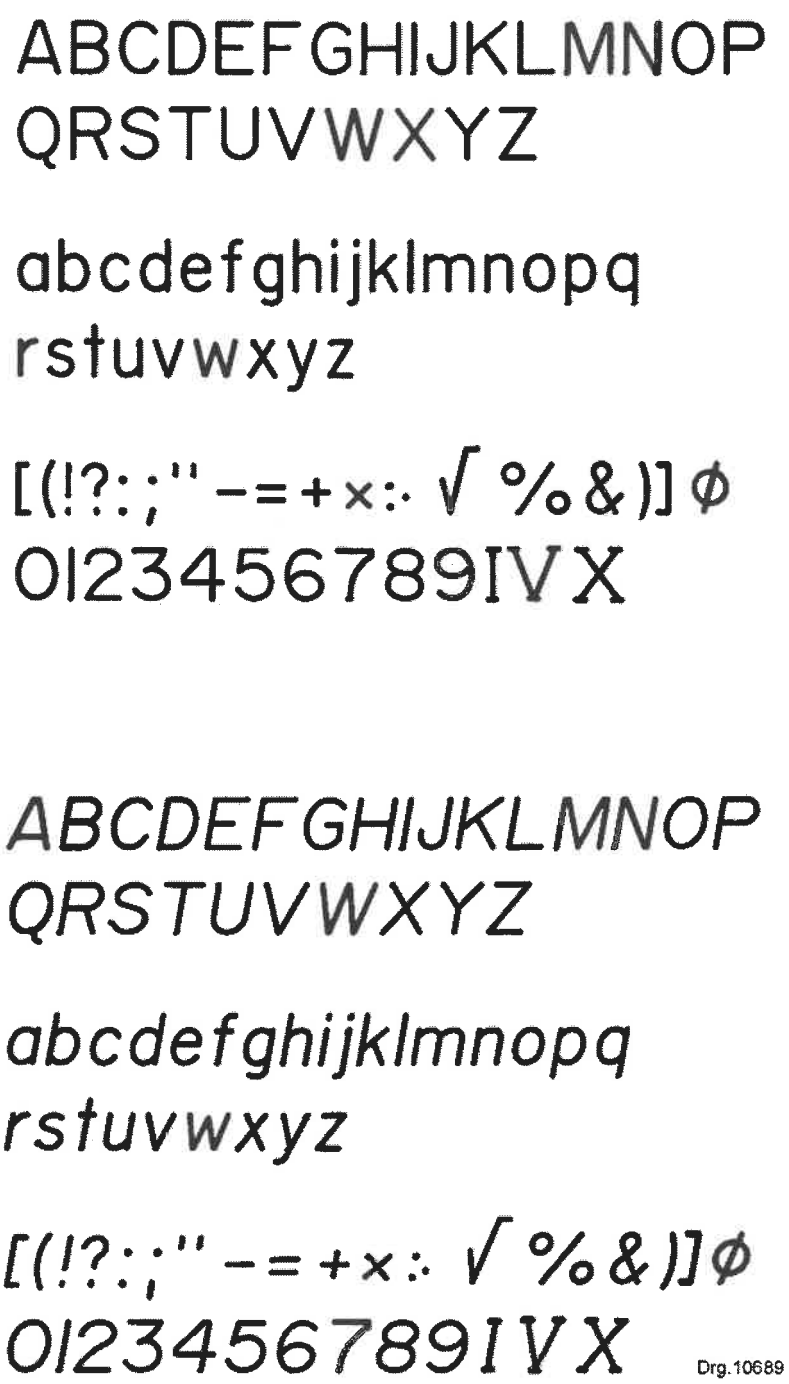


Figure 8 — Acceptable types of letters, figures and symbols (Universal)

4.2.3 Size and spacing of letters and figures

a) **Height and line thickness**. The height *h* of capital letters is taken as the basis for dimensioning. The standard values of *h* are 2,5 mm; 3,5 mm; 5 mm; 7 mm; 10 mm; 14 mm and 20 mm. (The ratio between successive standard values is approximately $\sqrt{2}$. This ratio is derived from the standardized progression of dimensions for the A-series of paper sizes.) The height and the line thickness of the characters on a drawing should conform to the relevant values given in table 4.

The value for both *h* and *c* (height of lower-case letters) should be at least 2,5 mm.

This means that when capitals and lower-case letters are used together and the value of *c* is 2,5 mm, *h* will be 3,5 mm.

Table 4 — Height and line thickness of characters

1	2	3	4	5
Application	**Drawing sheet size**	**Character height *h***	**Line thickness (ink) *d***	**Line thickness (pencil) *d***
		mm, min.	mm, min.	mm, min.
Drawing numbers, etc.	A0, A1, A2 and A3	7	0,7	0,7
	A4	5	0,5	0,5
Dimensions and notes	A0	3,5	0,35	0,3
	A1, A2, A3 and A4	2,5	0,25	0,3

b) **General dimensions**. The symbols designating the various dimensions and spacing of letters and figures are given in figure 9 and the values that should be used are given in table 5.

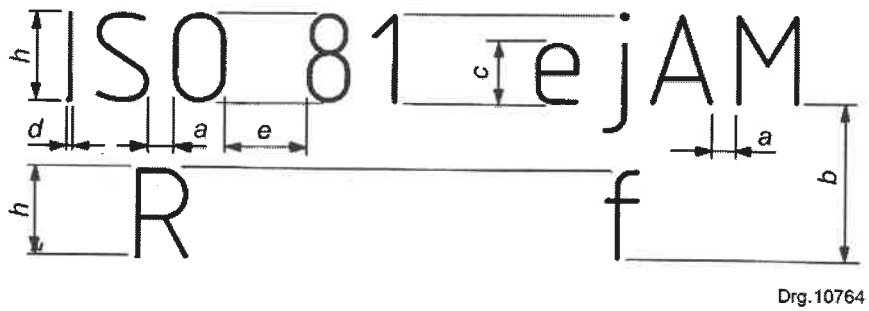


Figure 9 — Symbols designating the dimensions and spacing of letters and figures

Table 5 — Dimensions and spacing of lettering

1	2	3	4	5	6	7	8	9
Characteristic	**Symbol***	**Dimensions** mm						
Height of capital letters	h	2,5	3,5	5	7	10	14	20
Height of lower-case letters (without ascender or descender)	$c = (7/10)\,h$	–	2,5	3,5	5	7	10	14
Spacing between characters+	$a = (2/10)\,h$	0,5	0,7	1	1,4	2	2,8	4
Spacing between base lines, min.	$b = (14/10)\,h$	3,5	5	7	10	14	20	28
Spacing between words, min.	$e = (6/10)\,h$	1,5	2,1	3	4,2	6	8,4	12
Thickness of lines (in ink)	$d = (1/10)\,h$	0,25	0,35	0,5	0,7	1	1,4	2
*See figure 9. +Proportional spacing, where the space between each pair of letters is varied, is also acceptable.								

4.3 Arrowheads

a) The arrowhead should be drawn as a short line forming barbs at any convenient included angle between 15° and 90°. The arrowhead may be open, closed, or closed and filled in.

b) The size of the arrowhead should be proportionate to the size of the drawing, but not larger than is necessary for clarity.

c) Only one style of arrowhead termination should be used on a single drawing.

5 Layout of drawings

5.1 Information

The necessary information (on the drawing) should be given in a clear, concise manner and the drawing should not be complicated by over-elaborate and unnecessary views or with verbose notes.

5.2 Spacing

Details of components, views and notes should be spaced far enough apart to give clarity to the finished drawing.

5.3 Notes

Notes should be placed adjacent to the details of components or views to which they refer unless this reduces clarity, in which case the notes should be tabulated.

5.4 Underlining

Notes on drawings should not be underlined.

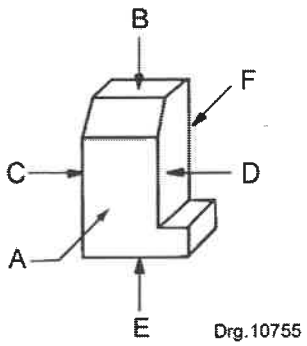
5.5 Emphasizing

Where a note or heading has to be emphasized, the characters should be larger than those used for other notes or headings.

6 Projection

6.1 Designation of views

The views depicted in a drawing are designated as shown in figure 10.



Front view – View in direction of arrow A
Top view – View in direction of arrow B
Left view – View in direction of arrow C
Right view – View in direction of arrow D
Bottom view – View in direction of arrow E
Rear view – View in direction of arrow F

Figure 10 — Designation of views

6.2 Systems of projection

Either first angle projection (see 6.2.1) or third angle projection (see 6.2.2) should be used, and the system of projection used should be clearly indicated, by means of a symbol (see figures 11 and 12) adjacent to the scale or by means of a note prominently shown on the drawing. Where a particular view is not projected in accordance with the system generally adopted on the drawing, or where there is any doubt as to which system of projection has been used for a view, a note should be added, with an arrow to indicate the direction of viewing.

6.2.1 First angle projection

In first angle projection, with reference to the front view, A, the other views should be arranged as follows (see figure 11):

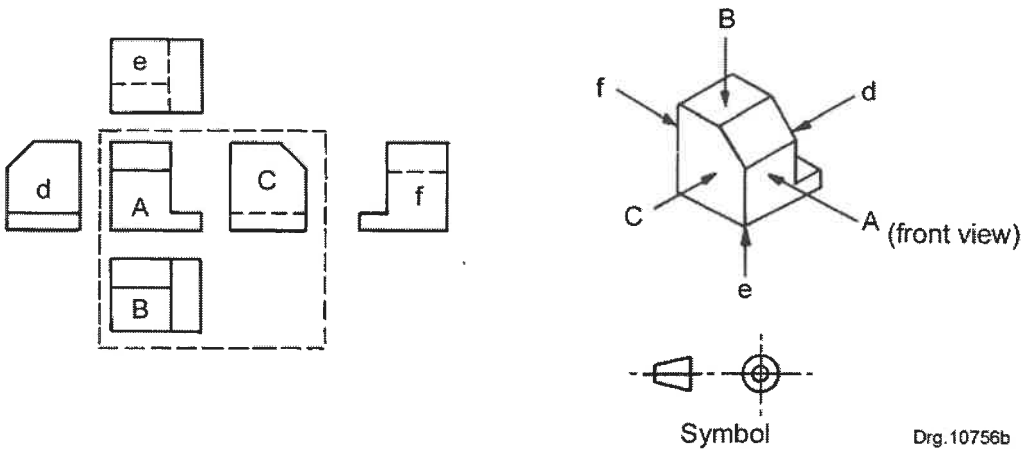
a) top view, B, is placed below;

b) left view, C, is placed on the right;

c) right view, d, is placed on the left;

d) bottom view, e, is placed above; and

e) rear view, f, is placed on either the left or the right, as convenient.



NOTE A, B, C are primary views (first choice) and
d, e, f are secondary views (second choice).

Figure 11 — First angle projection

6.2.2 Third angle projection

In third angle projection, with reference to the front view, A, the other views should be arranged as follows (see figure 12):

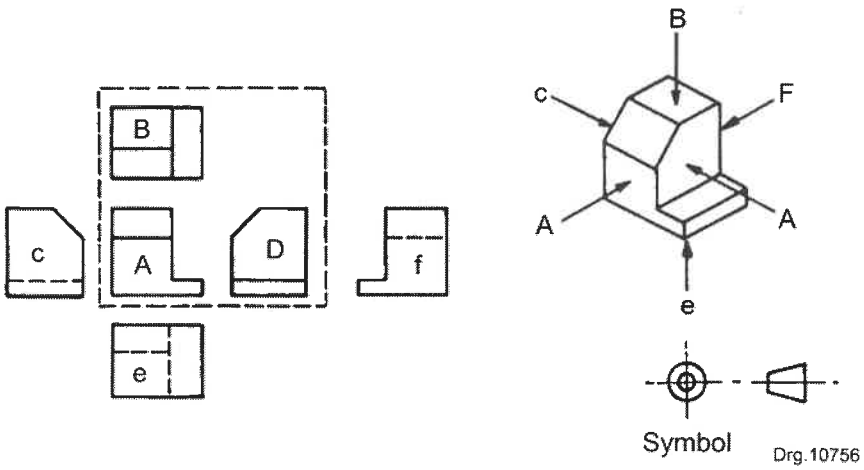
a) top view, B, is placed above;

b) left view, c, is placed on the left;

c) right view, D, is placed on the right;

d) bottom view, e, is placed below; and

e) rear view, f, is placed on either the left or the right, as convenient.



NOTE A, B, D are primary views (first choice) and
c e, f are secondary views (second choice).

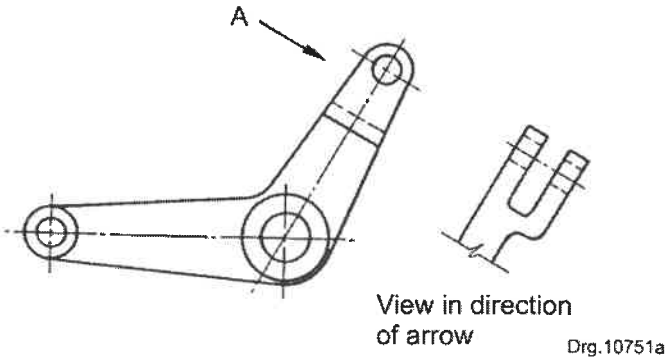
Figure 12 — Third angle projection

6.3 Number of views

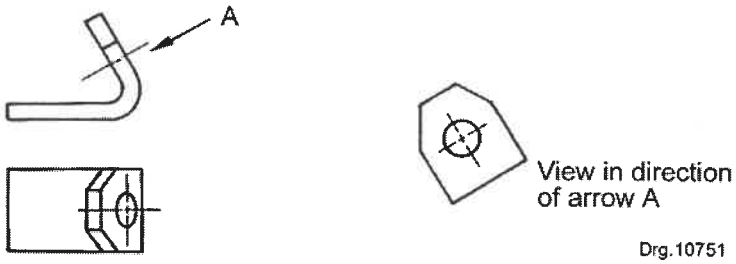
The number of views used should be restricted to the minimum necessary for clarity.

6.4 Auxiliary views

Components with an inclined part or face may have an auxiliary view projected to show the true shape of the inclined part, the direction of viewing being shown by an arrow (identified by a letter when necessary) as shown in figure 13. Whenever possible, a view of an inclined face should be shown in line with the direction of view (see figure 13(a)). When this is not possible, the view may be placed elsewhere (see figure 13(b)).



a) Partial auxiliary view projected from a full view



NOTE View title and arrow may be omitted if the measuring is clear without them.

b) Auxiliary view showing true shape of inclined face

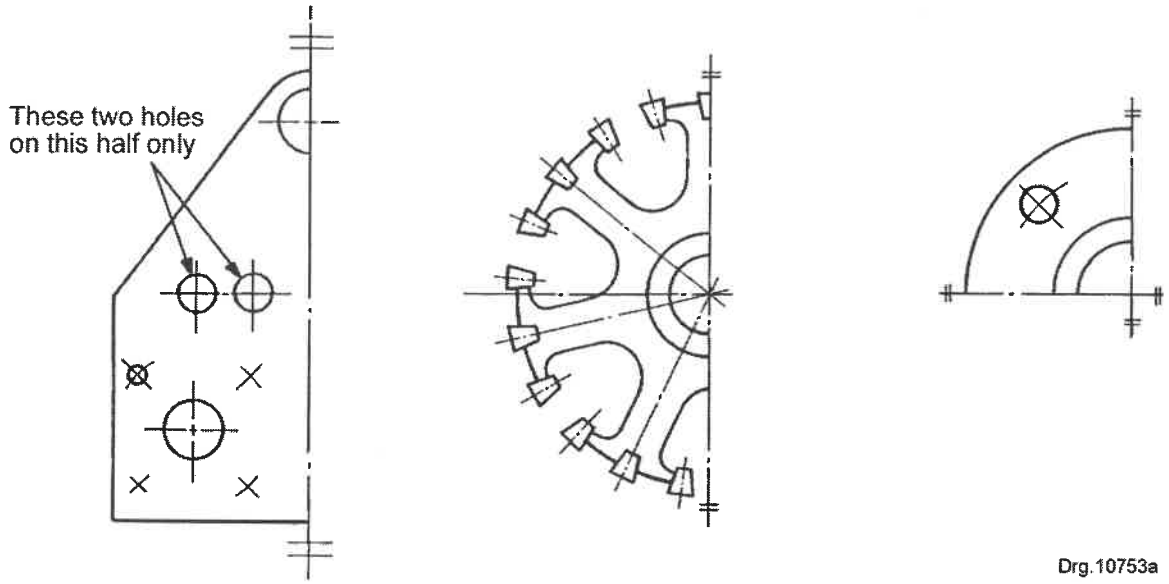
Figure 13 — Examples of auxiliary views

6.5 Partial and interrupted views

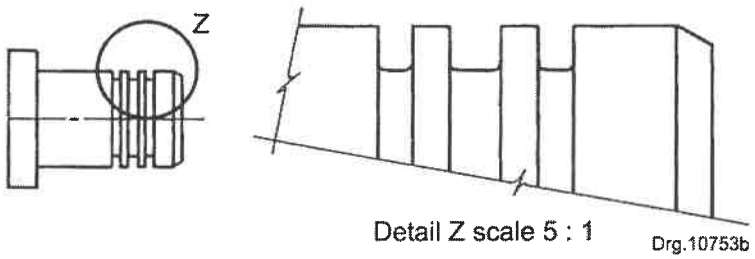
To save time and space on a drawing, partial and interrupted views may be used as follows:

a) **Partial view of symmetrical components**. A portion of a symmetrical component may be drawn to represent the whole (see figure 14(a)). The lines of symmetry should be identified by two short parallel strokes drawn at each end of, and at right angles to, the line(s) terminating the view.

b) **Enlarged partial view**. When required for clarity, an enlarged partial view may be drawn (see example in figure 14(b)).



a) Partial view of symmetrical components



b) Enlarge auxiliary partial view

Figure 14 — Examples of partial views

c) **Interrupted view**. Only those portions of a long component that are required for its definition should be drawn, the limits of the retained portions being defined by type C lines, and the retained portions being drawn close together (see figure 15).

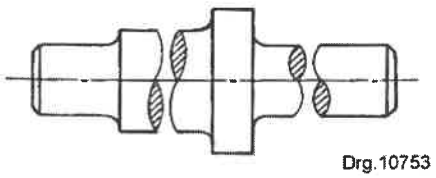


Figure 15 — Interrupted view

7 Sections and sectional views

7.1 General

7.1.1 Section or cross-section

Generally, a section or cross-section is a view or an outline taken at a cutting plane through a component that will be either a section or a sectional view.

a) **Section**. An elemental slice, having no substance, taken through a component, revealing the outline shape solely at the selected cutting plane.

b) **Sectional view**. The resultant view at a cutting plane, revealing detail of a component not otherwise readily visible, or including other visible outlines situated beyond that selected cutting plane when seen in the direction of viewing.

7.2 Hatching

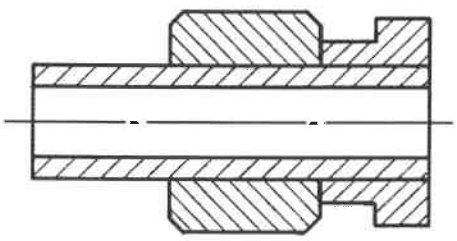
7.2.1 Standard hatching

a) Hatching should be used (preferably at an angle of 45° to the axis or main outline) to make the area sectioned evident (see figure 16). Hatching may be omitted where the meaning of the drawing is clear without it, but the practice followed should be consistent on any one drawing.

Drg.10752a

Figure 16 — Hatching of sections

b) The spacing between the hatching lines may vary according to the size of the section but should be the same in all sectional views of the same component drawn to the same scale. Hatching on adjacent components should be drawn in different directions or to a different spacing (see figure 17).



Drg.10752b

Figure 17 — Hatching interrupted for dimensions

c) Hatching may be interrupted for dimensions and lettering (see figure 18), or where necessary for clarity.

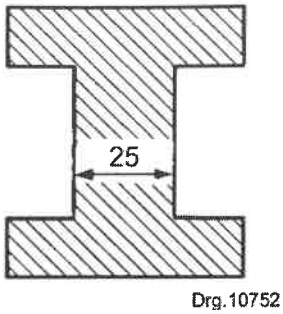


Figure 18 — Hatching interrupted for dimensions

d) In the case of a large area, the hatching may be limited to a zone following the outline of the area (see figure 19).

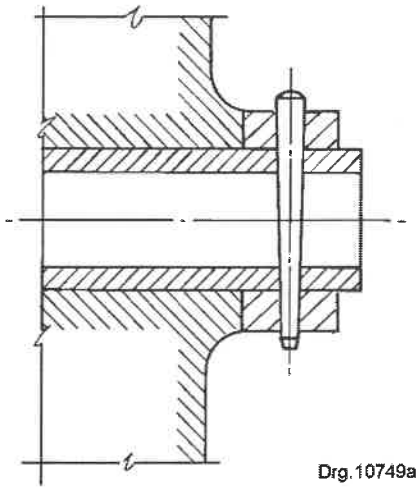


Figure 19 — Limited hatching

7.2.2 Thermal insulation, glass, wood, concrete, liquids and brickwork

Where necessary, sections through thermal insulation, glass, wood, concrete, liquids and brickwork should be indicated as shown in figure 20.

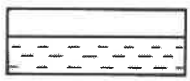
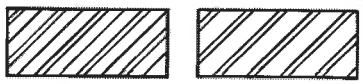
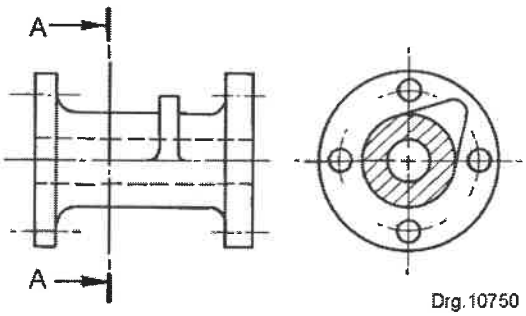
Materials	Convention
Thermal insulation	 Drg.10749
Glass	 Drg.10749b
Wood	 Drg.10749c
Concrete	 Drg.10749d
Liquids	 Drg.10749e
Brickwork	 Face Ordinary Drg.10749f

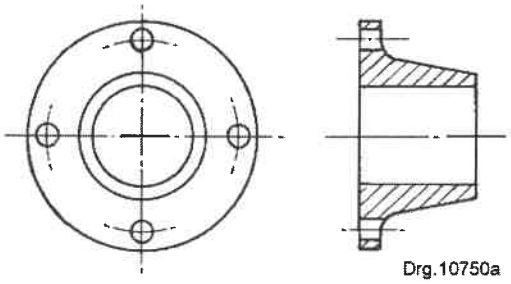
Figure 20 — Sections through thermal insulation, glass, wood, concrete, liquids and brickwork

7.2.3 Section lines

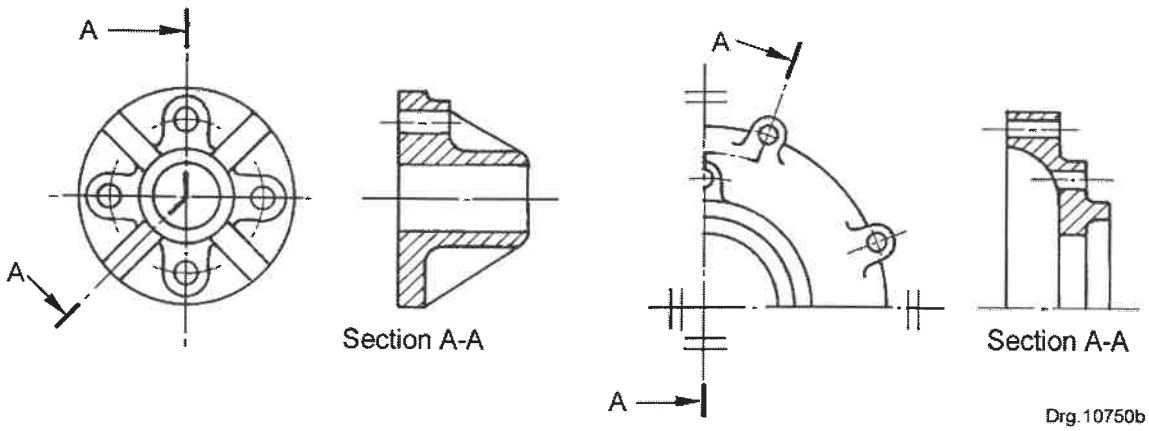
The position of the cutting plane may be shown, when necessary, by drawing a thin chain line, thickened at the ends and where it changes direction. Arrows indicating a cutting plane should be larger than those used for dimensioning. Arrows and letters at the end, outside the outline, should be added to indicate the direction in which the section is viewed (see figure 21(a) and (c)). When a sectional view is shown in one plane along a centre line, a section line is unnecessary (see figure 21(b)).



(a) Sectional view in one plane



(b) Sectional view in one plane along centre line (section lines not required)



(c) Sectional view in two planes

Figure 21 — Examples of section lines

7.3 Types of section

7.3.1 Half section

Components that are symmetrical about a centre line may be drawn with one half in outside view and one half in section. When the sectioned half of the view contains an area of hatching that touches the centre line, the centre line should be changed to a continuous thin line (see figure 22). Hidden features should not be shown unless they are necessary for clarity.

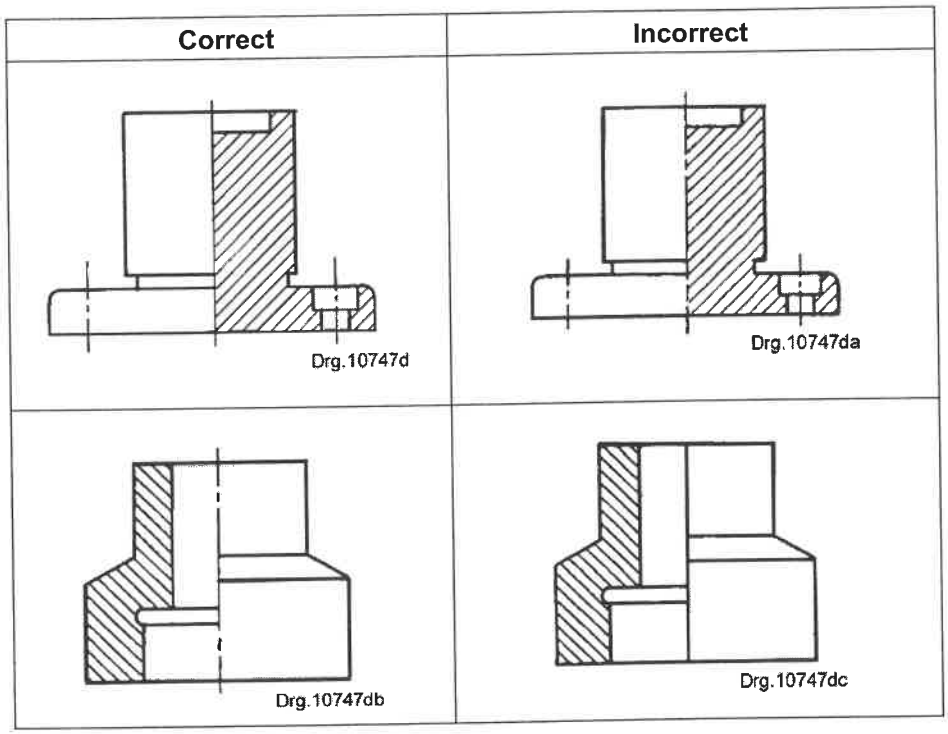


Figure 22 — Half section showing the correct and incorrect presentation

7.3.2 Part section

A view may be drawn in part section to show detail that would otherwise be hidden (see figure 23).

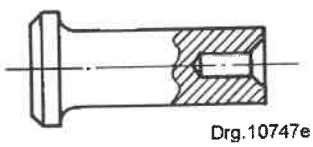


Figure 23 — Part section

7.3.3 Revolved section

A revolved section (see figure 24) is used to show the shape of a cross-section on the view of the component by revolving the cutting plane in position. A revolved section is a section (see 7.1.1(a)), not a sectional view (see 7.1.1(b)).

The outline of a revolved section is drawn with a continuous thin line. If a revolved section cannot be shown or dimensioned clearly in position, a removed section should be used instead (see 7.3.4).

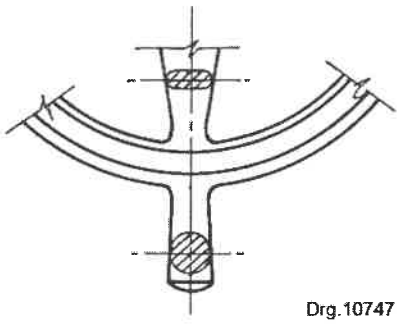


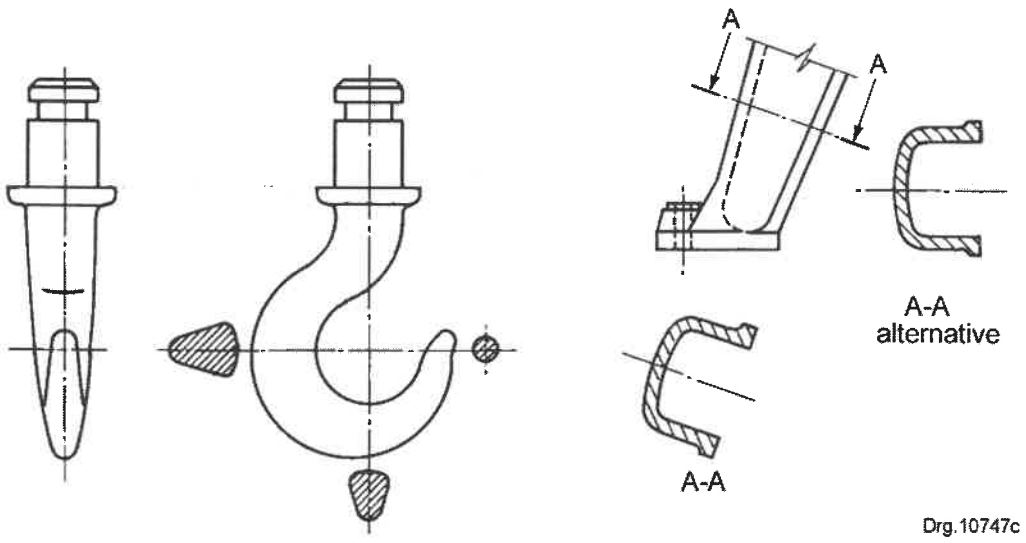
Figure 24 — Revolved section

7.3.4 Removed section

A removed section is also used to show the shape of the cross-section of a component. It may be placed near the view and, if applicable, connected with the view by its line of symmetry (thin chain line) through the cutting plane, as shown in figure 25(a).

Alternatively, it may be shown, conventionally identified, either in projection or in any convenient place on the drawing (see figure 25(b)).

If a removed section is not symmetrical, one of the methods shown in figure 25(b) should be used. In all cases, the outline of the section should be drawn with a continuous thick line.



(a) Connected with the view by its line of symmetry

(b) Conventional representation

Figure 25 — Removed section

7.3.5 Sections of thin components

Sections of components that are too thin for hatching may be blackened (i.e. filled in solid), and a space left between adjacent components (see figure 26).

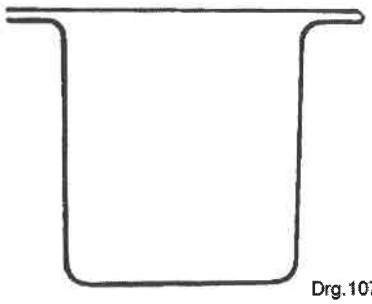
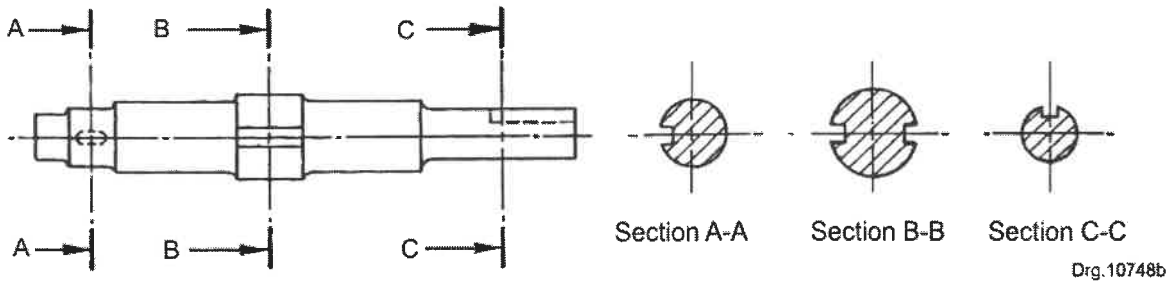


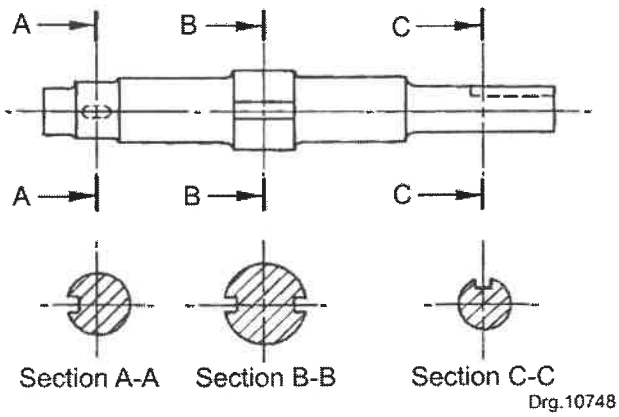
Figure 26 — Section of thin components

7.3.6 Successive sections

The method shown in figure 27(a) should be used to show successive sections, unless lack of space makes it necessary to adopt the arrangement shown in figure 27(b).



(a) Preferred arrangement



(b) Alternative arrangement

Figure 27 — Successive sections

7.3.7 Exceptions

Ribs, shafts, bolts, nuts, rivets, rods, keys, pins and similar components should not be sectioned when the cutting plane passes longitudinally through them (see figure 28).

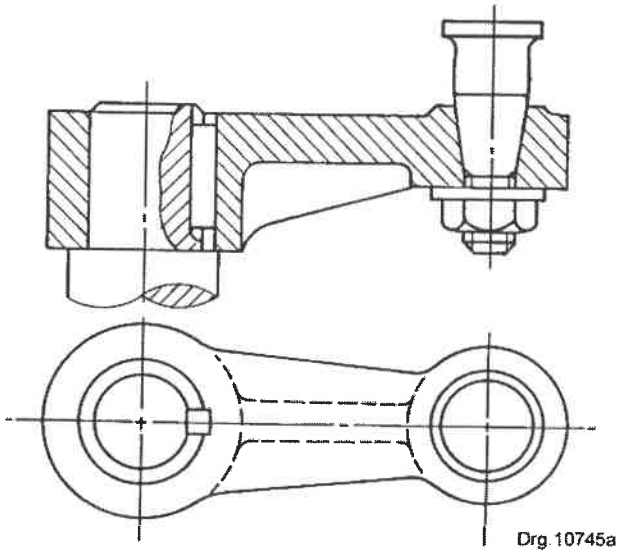


Figure 28 — Rib, shaft, key, crank pin, nut and washer, not sectioned

8 Conventional representation of common features

8.1 Common features

To save time and space when a commonly occurring feature is being drawn, conventional representations may be used, preferably in the simplified form, where applicable, as given in figure 30.

8.1.1 Squares and other flat faces

Flat faces such as squares, tapered squares and local flats may be indicated by crossed diagonal thin lines (see figure 29).

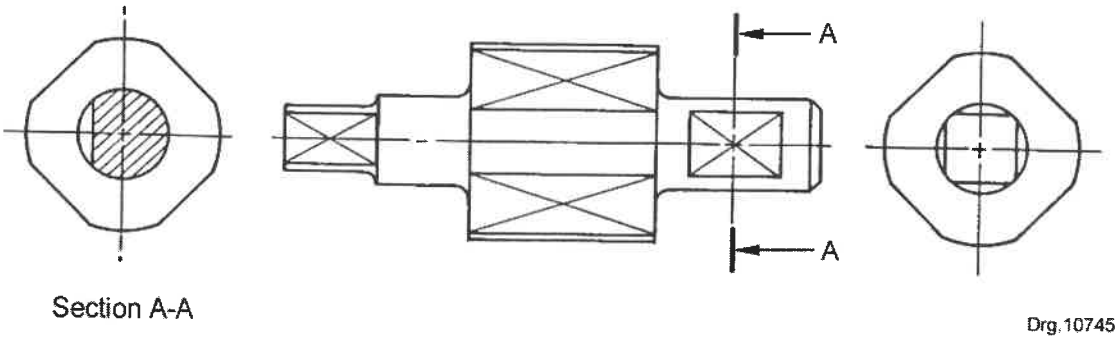


Figure 29 — Square on a shaft and flat face on a cylinder

8.1.2 Other conventional representations

Other conventional representations are shown in figure 30.

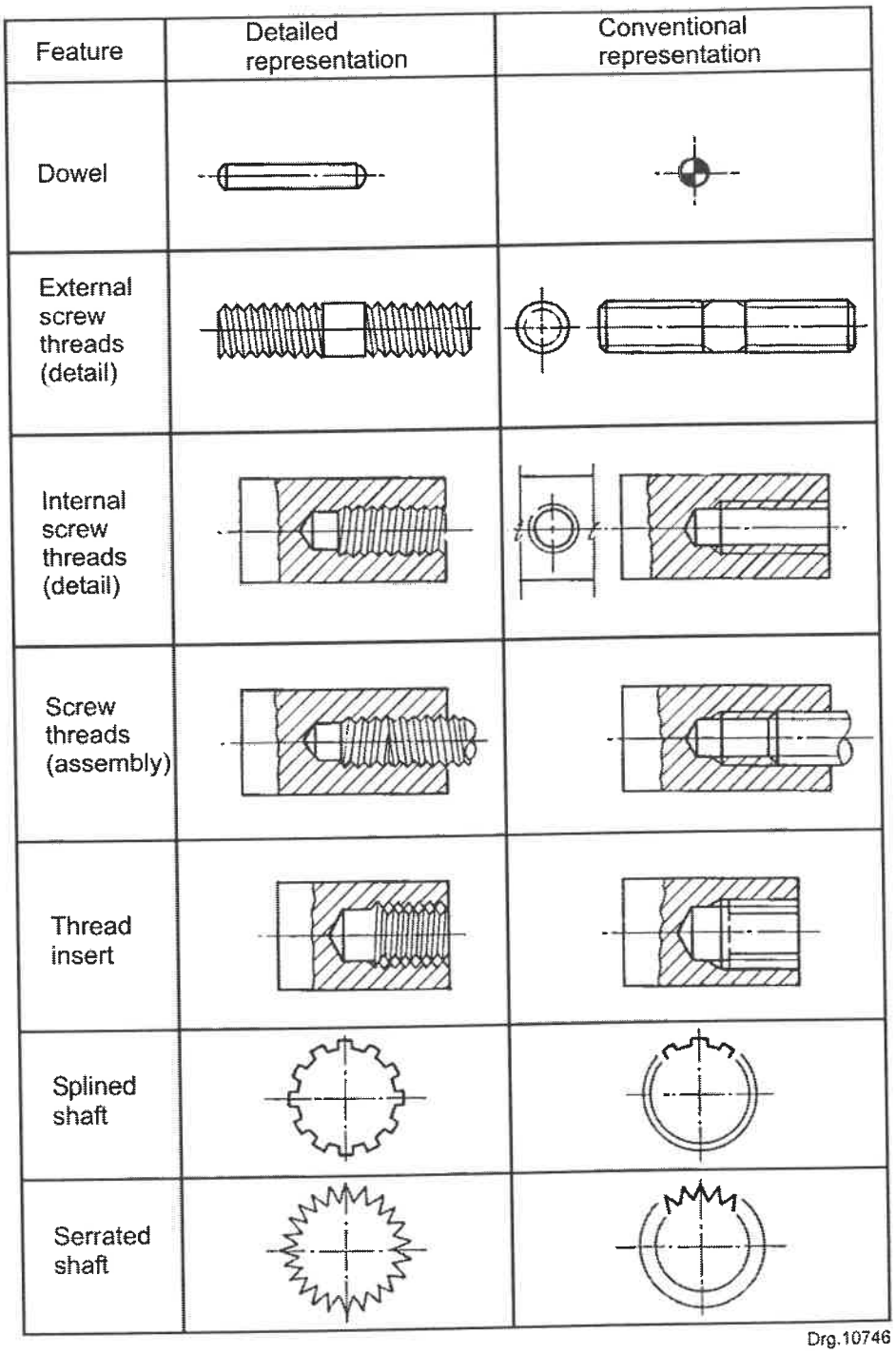


Figure 30 — Conventional representation of common features

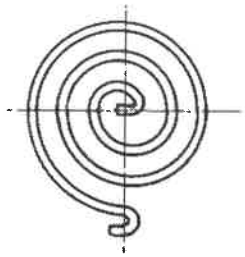
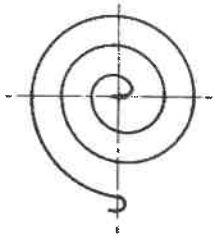
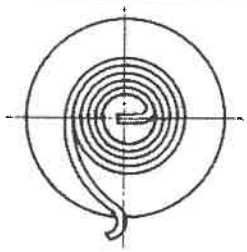
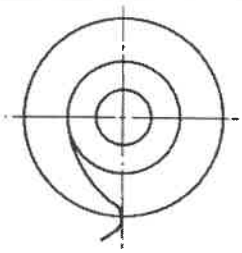
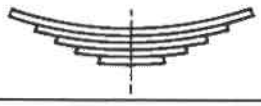
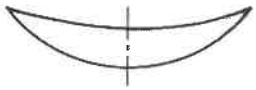
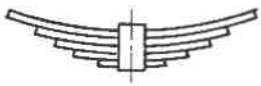
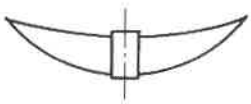
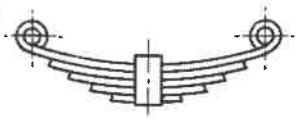
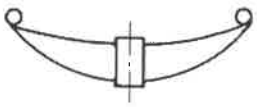
Feature	Conventional representation	
	View	Simplified
Spiral spring		
Spiral spring (the spring is wound by rotating the box)		
Semi-elliptic leaf spring		
Semi-elliptic leaf spring with eyelets		
Semi-elliptic leaf spring with centre band (buckle)		
Semi-elliptic leaf spring with eyelets and centre band (buckle)		

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Figure 30 *(continued)*

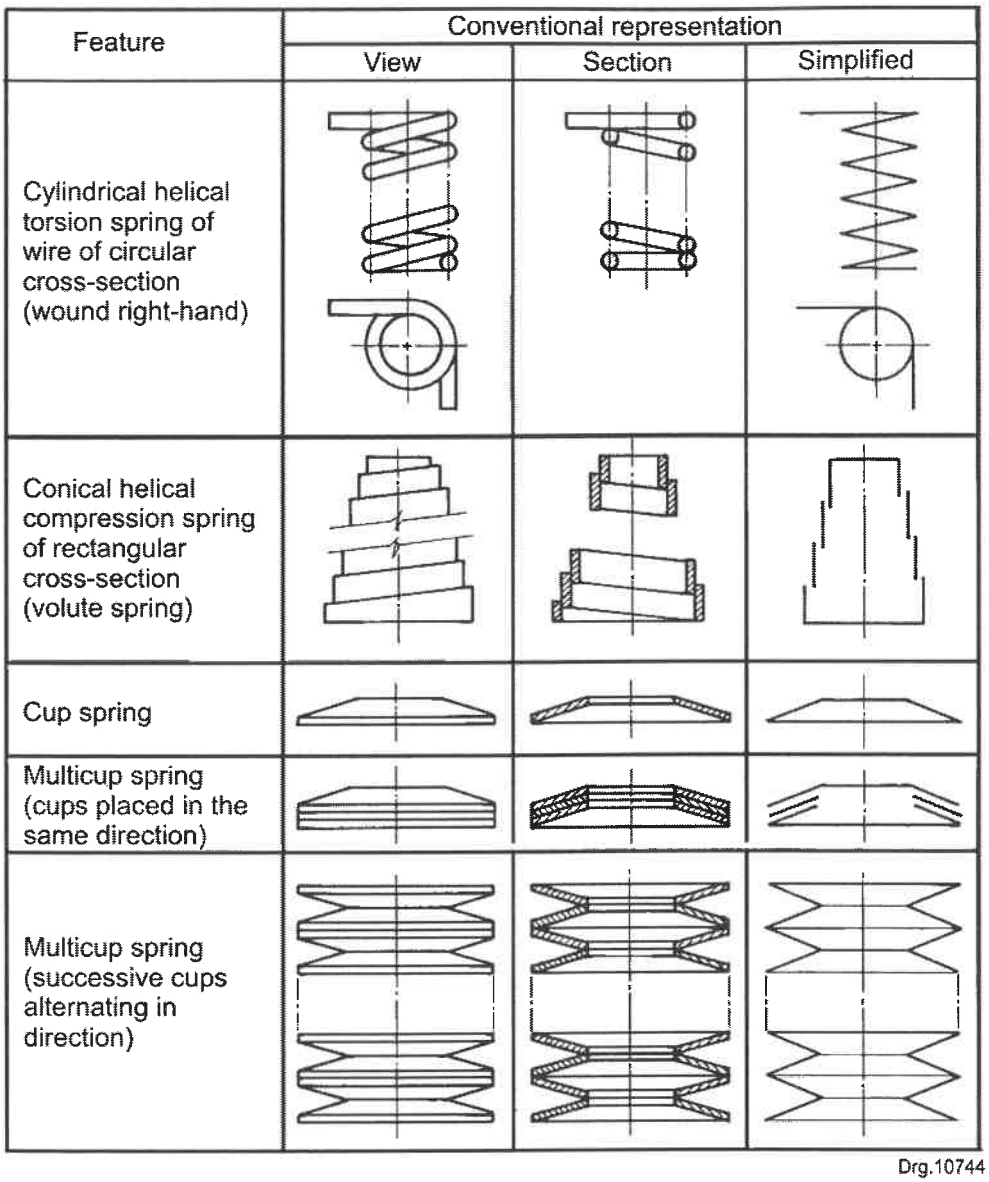


Figure 30 *(continued)*

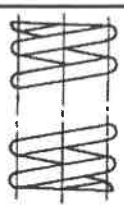
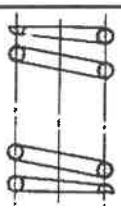
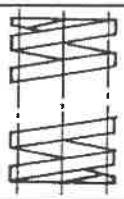
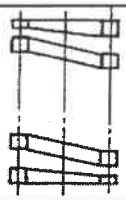
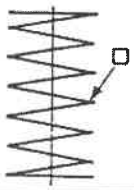
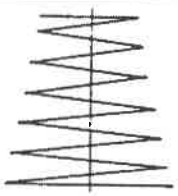
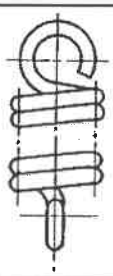
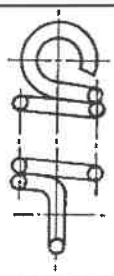
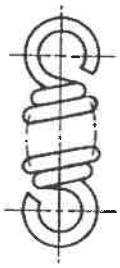
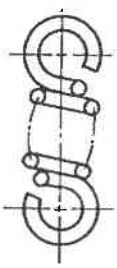
Feature	Conventional representation		
	View	Section	Simplified
Cylindrical helical compression spring of wire of circular cross-section			
Cylindrical helical compression spring of wire of rectangular cross-section			
Cylindrical helical compression spring of wire of circular cross-section			
Cylindrical helical tension spring of wire of circular cross-section			
Barrel-shaped helical tension spring of wire of circular cross-section			

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Figure 30 *(continued)*

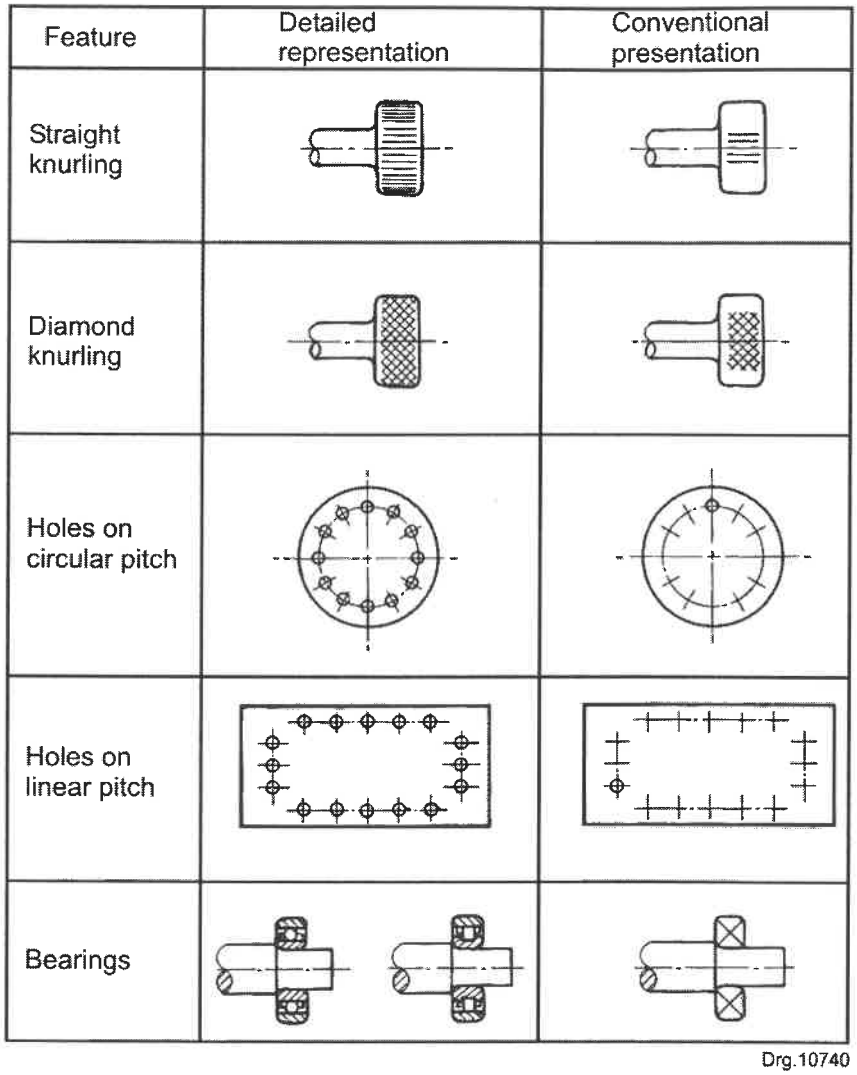


Figure 30 *(continued)*

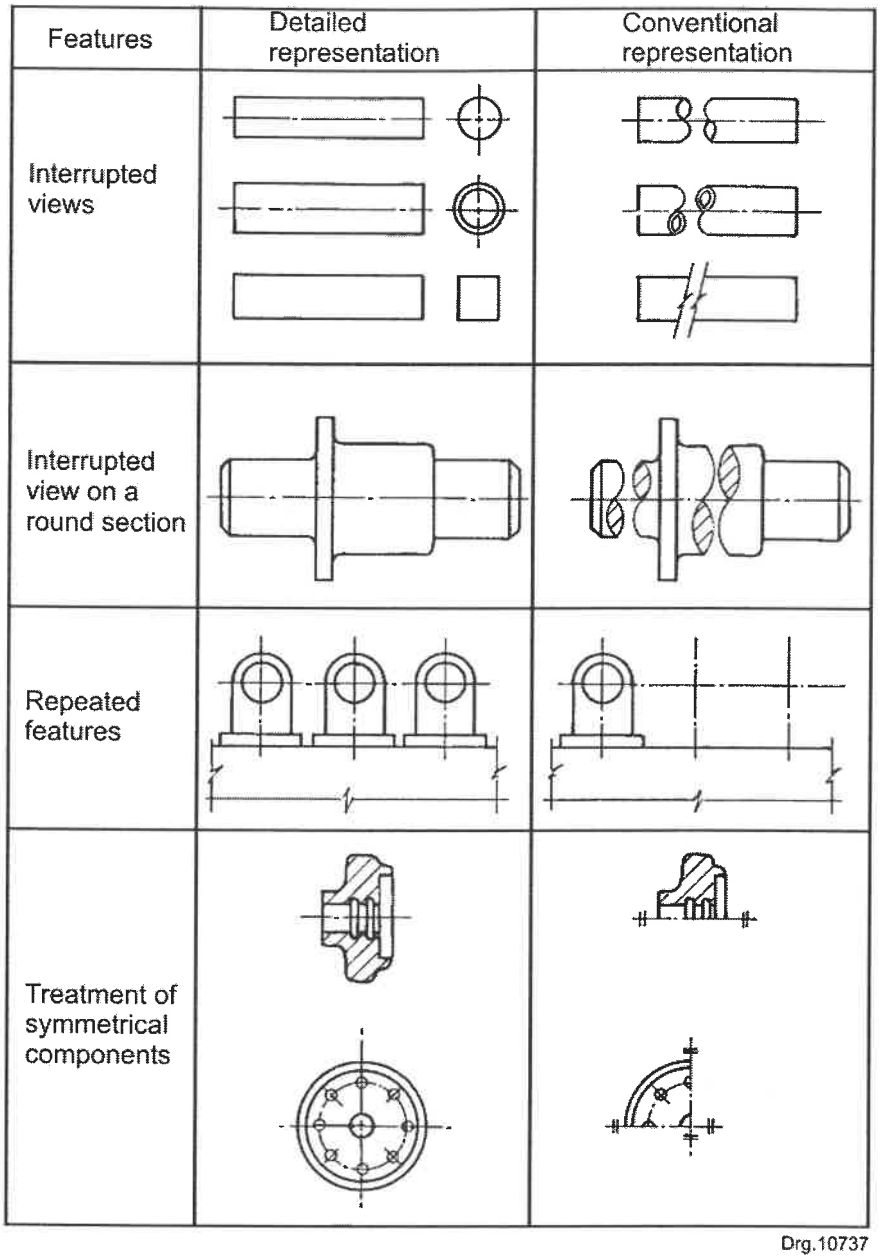


Figure 30 *(concluded)*

8.2 Gears

8.2.1 General

Except in the case of an axial section, a gear should be represented as a solid component without teeth, but with the addition of the pitch surface in a thin chain line. Detailed rules are given in 8.2.2 to 8.2.6 (inclusive). (See also the examples in figure 31.)

8.2.2 Contours and edges

Contours and the edges of each gear should be represented as if the gear were

a) in an unsectioned view, a solid gear bounded by the tip surface, and

b) in an axial section, a spur gear having two diametrically opposed teeth, represented unsectioned, even in the case of a gear that does not have spur teeth or has an odd number of teeth.

8.2.3 Pitch surface

The pitch surface should be drawn with a thin long chain line, even in concealed portions and sectional views. It should be represented

a) in a projection normal to the axis, by its pitch circle (the external pitch circle in the case of a bevel gear and the median pitch circle in the case of a worm wheel) (see figure 31), and

b) in a projection parallel to the axis, by its apparent contour, the line being extended beyond the gear contour on each side (see figure 31).

8.2.4 Root surface

As a general rule, the root surface should not be represented except in sectional views. However, if it seems helpful to show the root surface also on unsectioned views, it should always be drawn as a thin continuous line.

8.2.5 Teeth

Tooth profile should be specified either by reference to a standard or by a drawing to a suitable scale. If it is essential to show one or two teeth on the drawing itself (either to define the ends of a toothed portion or rack, or to specify the position of the teeth in relation to a given axial plane), they should be drawn as thick continuous lines.

8.2.6 Assembly drawings (gear pairs)

The specified rules for the representation of gears on detail drawings are equally applicable to assembly drawings. However, for a pair of bevel gears in projection parallel to the axis, the line drawn for the pitch surface should be extended to the point where the axes meet (see the second feature in figure 31).

Neither of the two gears of a gear pair should be assumed to be hidden by the other in the portion in mesh, except in the following two cases:

a) If one of the gears, the whole of which is located in front of the other, effectively conceals part of the other gear (see the second feature in figure 31); or

b) if both gears are represented in axial section, in which case one of the two gears, chosen arbitrarily, is assumed to be partly concealed by the other (see the second, fourth and seventh features in figure 31).

In these two cases, concealed contour edges need not be represented unless they are necessary for clarity (see the second feature in figure 31).

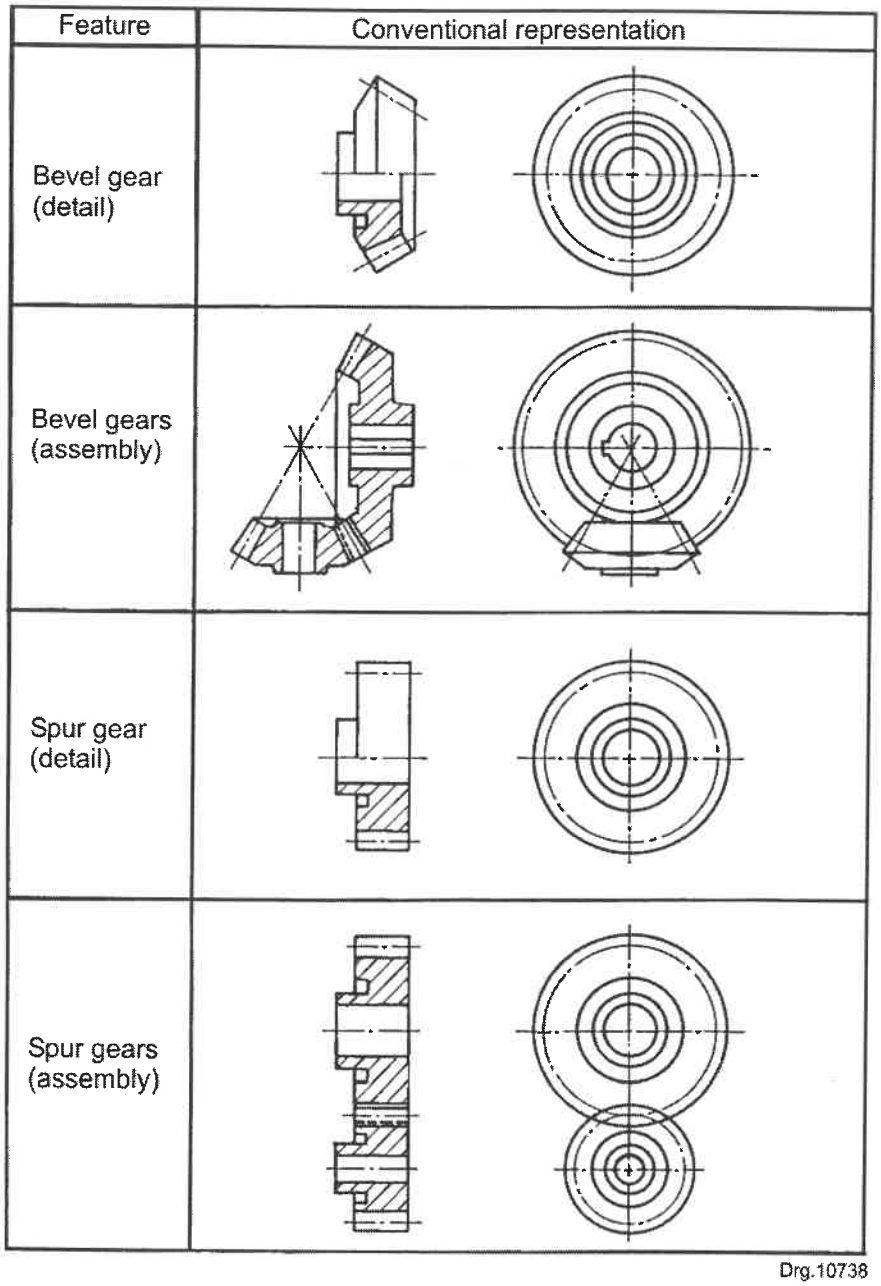
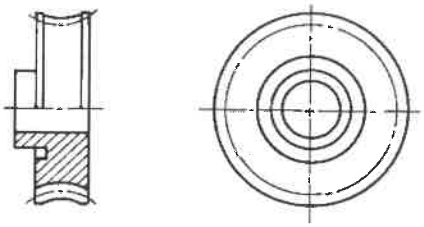
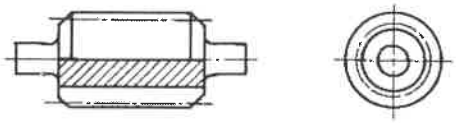
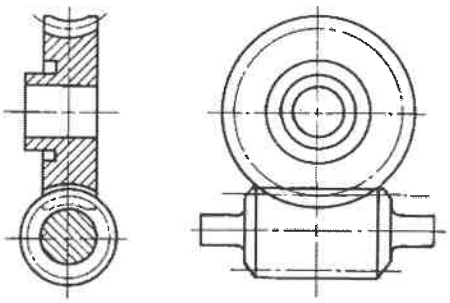
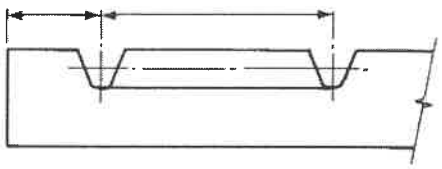
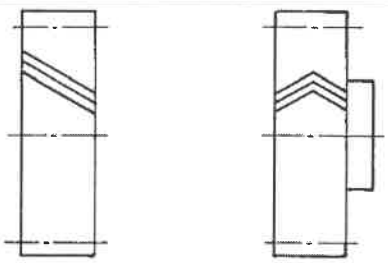


Figure 31 — Conventional representation of gears

Feature	Conventional representation
Wormwheel (detail)	
Worm (detail)	
Wormwheel and worm (assembly)	
Toothed rack	
Teeth: indication of direction	

Drg.10736

Figure 31 *(concluded)*

9 Dimensioning and tolerancing

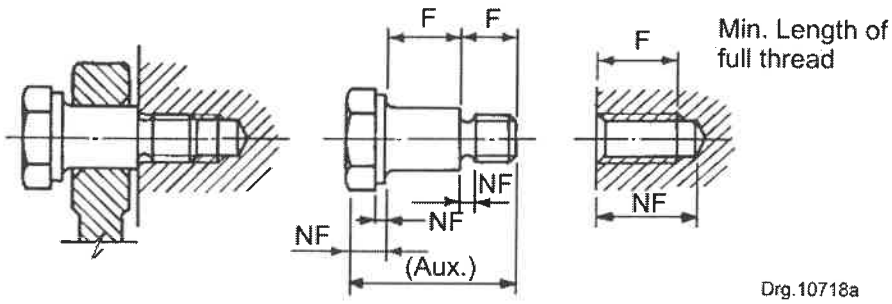
9.1 Terminology (see figure 32)

a) **Auxiliary dimension**. A redundant dimension given, without tolerances, on a drawing to provide useful information (see 9.5.4).

b) **Functional dimension**. A dimension that directly affects the function of a component.

c) **Non-functional dimension**. A dimension that is necessary to define a component but does not directly affect its function.

d) **Redundant dimension**. A dimension that is not necessary to define a component and does not directly affect its function (see 9.5.4).



F = A functional dimension
NF = A non-functional dimension
Aux = An auxiliary dimension given, without tolerances, for information only

Figure 32 — Terminology of dimensions

9.2 Dimensioning

9.2.1 General

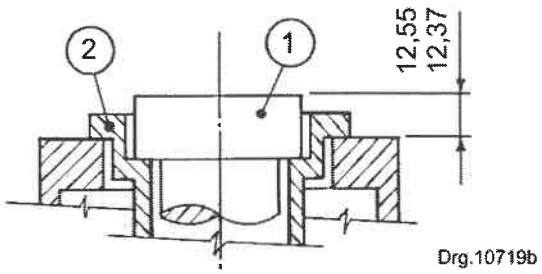
Each dimension necessary for the complete definition of a component should be given once only and, except for auxiliary dimensions, redundant dimensions should not be given.

9.2.2 Functional dimensions

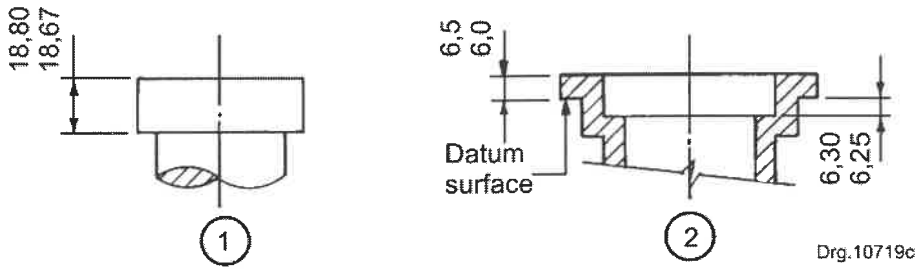
All functional dimensions should be given directly on the drawing.

The application of this principle will necessitate the selection of datum features on the basis of the function of the component and the method of locating it in any assembly. If any datum feature other than one based on the function of the component is used, finer tolerances will be necessary and components that would satisfy the functional requirements may be rejected for exceeding these finer tolerances. Figure 33 illustrates this point.

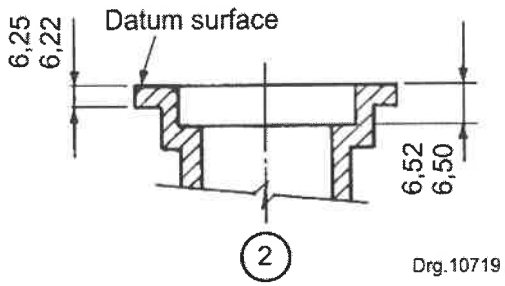
This recommendation does not preclude the preparation of special drawings, wholly dimensioned from a common datum point, to suit a particular numerically controlled machining system where it is known that the overall accuracy of the system will be adequate to ensure meeting the finer tolerances thus arising.



(a) Assembly drawing showing functional requirement



(b) Components 1 and 2 dimensioned from functional surface



(c) Component 2 redimensioned using top surface as datum surface. Tolerance have had to be reduced to keep the assembly within the limits 12,55 and 12,37

Figure 33 — Effect of using a datum surface not determined by functional requirements

9.2.3 Non-functional dimensions

Non-functional dimensions should be given that will aid production or inspection or both.

9.2.4 Dimensions not to scale

Where any part of a view is not drawn to the given scale, the note "Dimensions are not to scale" should be added, or "NTS" printed after the relevant dimensions, or the dimensions underlined (see figure 34) with a thick line. Underlining is not recommended for drawings that are to be microfilmed.

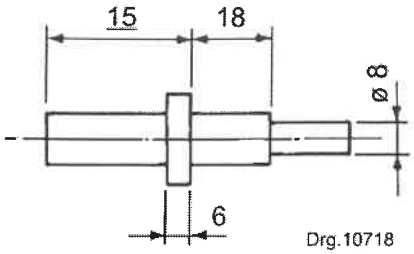


Figure 34 — Dimensions not to scale

9.2.5 Equal dimensions

When a dimension is divided into several equal parts, the sign = may be used to indicate those dimensions that are nominally equal (see figure 35).

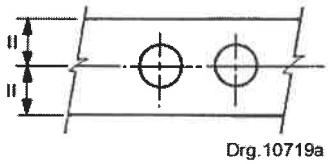


Figure 35 — Equal dimensions

NOTE This practice is not recommended for precision work.

9.2.6 Precision work

In the case of precision work, given dimensions of the finished component are applicable at a temperature of 20 °C, and this should be stated on the drawing.

NOTE The term "finished component" refers to the component in the condition in which it is to be used and includes any specified surface treatment other than painting, lacquering or other similar finishes.

9.3 Projection lines, dimension lines and leaders

9.3.1 Projection lines

a) **Type of line**. Continuous thin lines should be used, so projected from points, lines or surfaces that the dimensions can, wherever possible, be placed outside the outline.

b) **Projection lines that are extensions of lines of the outline**. The projection lines should be started just clear of the outline and should extend to just beyond the dimension line (see figure 36).

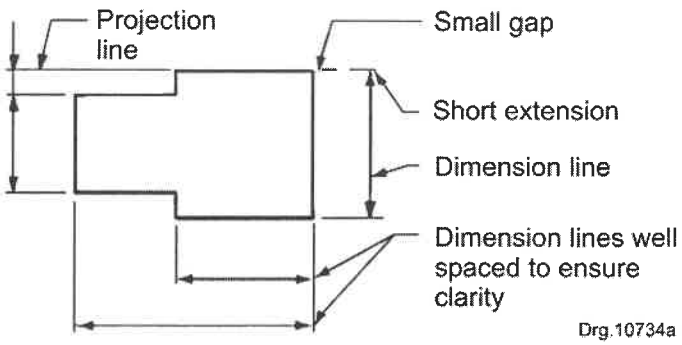


Figure 36 — Projection and dimension lines

c) **Projection lines that refer to points on surfaces or to points of intersection**. The projection lines should touch or pass through the points (see figures 37 and 38).

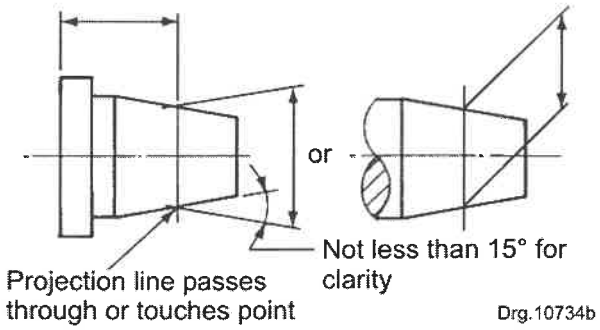


Figure 37 — Projection lines from points on surfaces

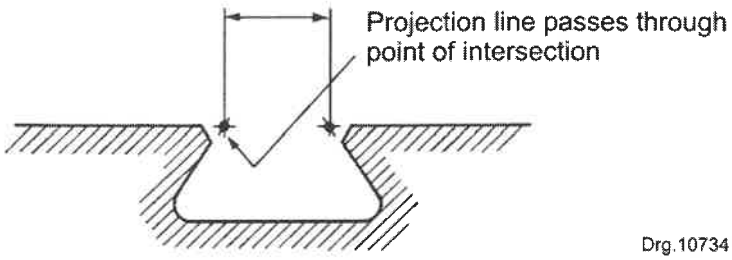


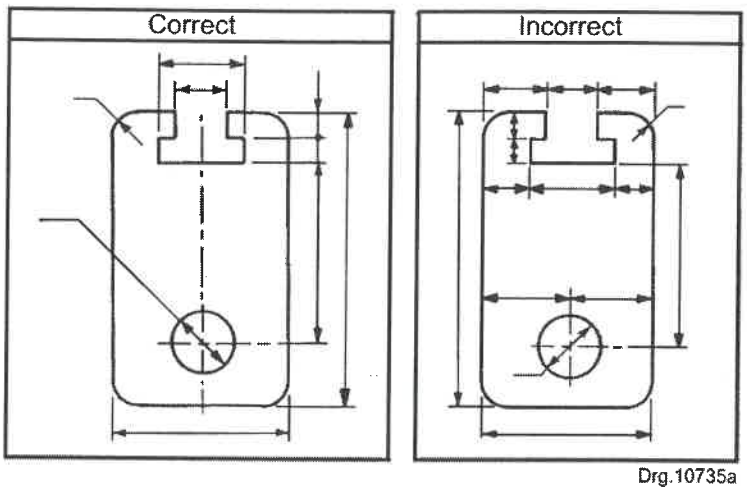
Figure 38 — Points of intersection emphasized by dots

9.3.2 Dimension lines

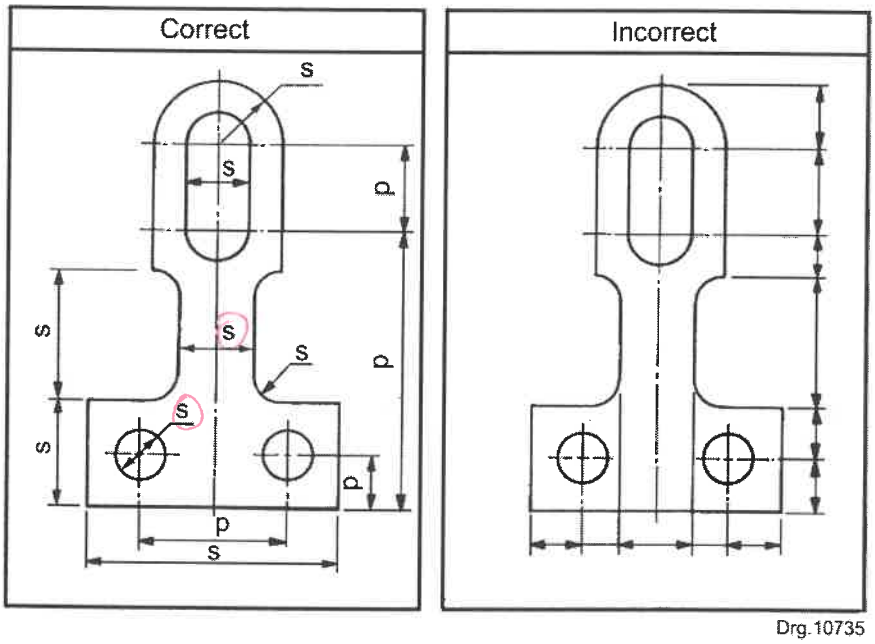
a) **Type of line**. Continuous thin lines should be used and, wherever possible, placed outside the outline. A dimension line may, if necessary, be interrupted for the insertion of the dimension. Arrowheads (see 4.3) should be sharply defined, and their points should touch the projection or other limiting lines.

A centre line or part of an outline should never be used as a dimension line, but may be used as a projection line.

The introduction of an axis of symmetry can result in great simplification of dimensions (see figure 39(a)). It is good practice to separate dimensions giving information about the position of a feature from dimensions giving information about the size of the feature (see figure 39(b)).



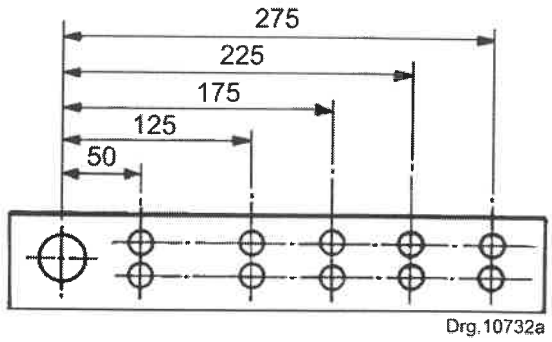
(a) Dimensions simplified by the introduction of an axis of symmetry



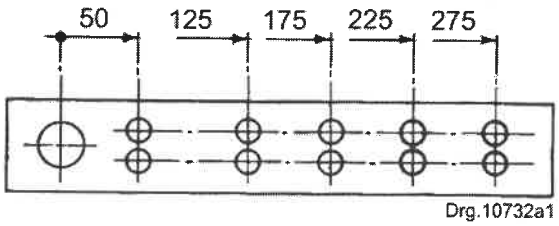
(b) Use of the rule of separating size dimensions from positional dimensions

Figure 39 — Good and bad practice in the use of dimension lines

b) **Dimensions from a common datum line**. Except where space restriction necessitates the use of the alternative method, the normal method (see figure 40(a)) should be used to give a number of dimensions from a common datum line. In the alternative method, the dimensions should be placed near the appropriate arrowheads, for purposes of clarity. A dot may replace a single arrowhead to indicate the common origin of successive dimensions (see figure 40(b)).



(a) Normal method

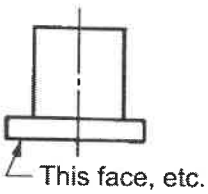


(b) Alternative method

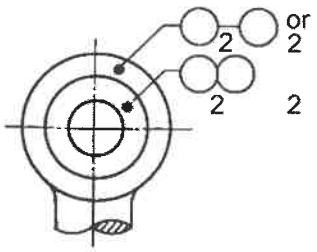
Figure 40 — Dimensions from a common datum line

9.3.3 Leaders

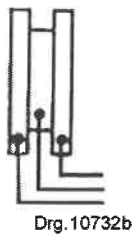
a) **Type of line**. A continuous thin line should be used, terminating in an arrowhead or a dot, for a leader line (leader) to indicate where a dimension or note is to apply. An arrowhead should terminate on a line, and a dot should be located within the outline of the component or between projection lines, where space is limited (see figure 41).



(a) Leader terminating in arrow head



(b) Leader terminating in dots, and method of item references showing the quantities



(c) Leader where space is limited

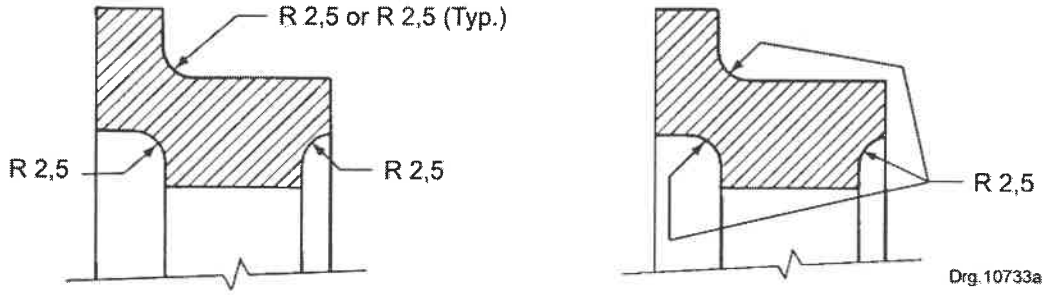
Figure 41 — Typical leaders

b) **Leaders that touch lines**. A leader should be so drawn that it touches a line normal or nearly normal to the line (see figure 42).

(a) Correct (b) Incorrect

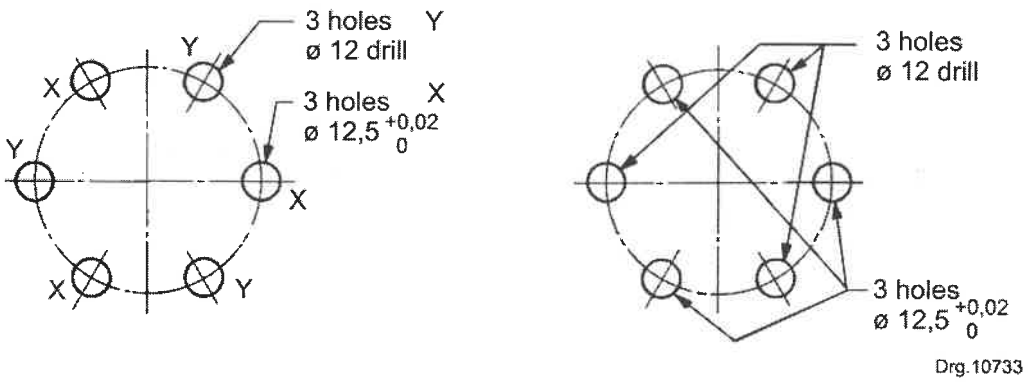
Figure 42 — Leaders that touch lines

c) **Long leaders**. Long leaders should be avoided even if their avoidance requires the repetition of dimensions or notes (see figure 43), or the use of letter symbols (see figure 44).



(a) Correct (b) Incorrect

Figure 43 — Use of repeated dimensions to avoid long leaders



(a) Correct (b) Incorrect

Figure 44 — Use of letter symbols to avoid long leaders

9.4 Units and format of dimensions

9.4.1 Unit of measurement

Linear dimensions should be expressed in millimetres and should be indicated clearly on the drawing.

9.4.2 Decimal dimensions

Decimal dimensions should be expressed to the lowest number of decimal places consistent with the design requirements and the use of basic sizes.

9.4.3 Use of comma

A decimal comma should be used in preference to the decimal point, e.g. 24,505.

9.4.4 Use of the numeral "0"

When the dimension has a value that is less than one, the numeral "0" should be placed before the decimal comma, e.g. 0,5.

9.4.5 Spacing of digits

Every three digits of a dimension to the right and the left of a decimal comma should be separated by a full character space, e.g. 12 000,5 and 10,001 75.

9.4.6 Angular dimensions

Angular dimensions should be expressed in degrees, minutes and seconds, e.g. 22°; 22° 30'; 22° 30' 30". When the angle is less than 1°, the dimension should be preceded by 0°, e.g. 0° 15'; 0° 15' 10".

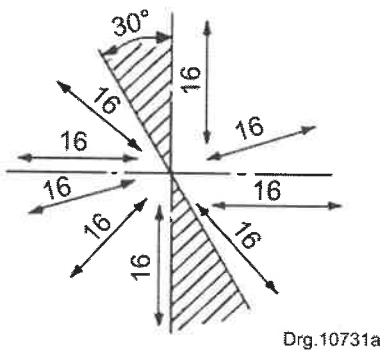
9.5 Arrangement of dimensions

9.5.1 Position of dimensions

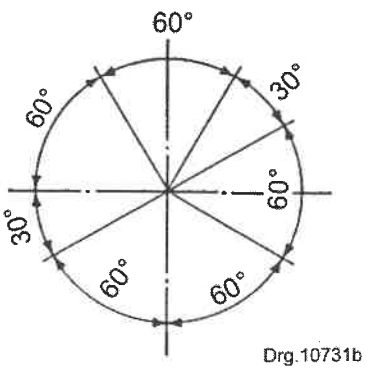
Figures and letters should be placed above and clear of, and preferably near the middle of, the appropriate dimension line and in such a way that they are not crossed or separated by any other line of the drawing. Dimensions should not be placed in a hatched area (see figure 45(a)), unless this is unavoidable.

9.5.2 Direction of reading

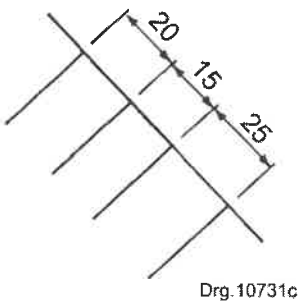
Dimensions shall be so orientated that they can be read from the bottom or from the right-hand side of the drawing (see figure 45(a) to (d)).



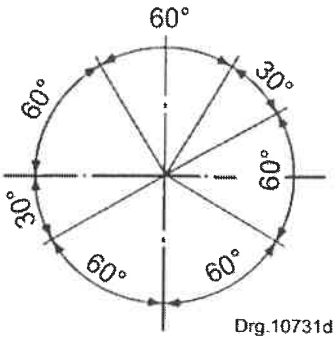
(a) Linear dimensions written parallel to the line



(b) Angular dimensions



(a) Linear dimensions written horizontally



(b) Angular dimensions written horizontally

Figure 45 — Dimensions orientated to read from the bottom or from the right-hand side of the drawing

9.5.3 Overall dimensions

Overall dimensions should be placed outside intermediate dimensions (see figure 46).

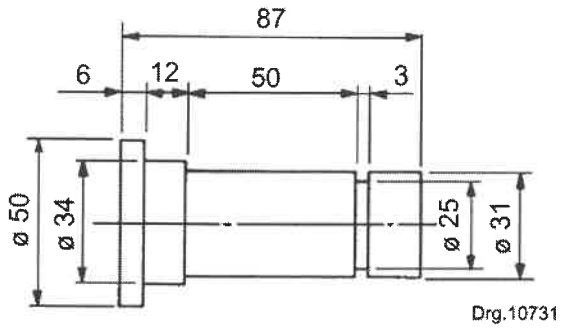


Figure 46 — Overall dimensions placed outside intermediate dimensions

9.5.4 Auxiliary and other redundant dimensions

Redundant dimensions (other than auxiliary dimensions) should not be given on a drawing. Auxiliary dimensions should be placed within brackets, and should not be toleranced.

Example 1. In figure 46, one of the dimensions in the string of intermediate dimensions has been omitted because it is redundant.

Example 2. In figure 47, the overall length is redundant but has been given in brackets as an auxiliary dimension because it provides useful information, namely the overall length of the component.

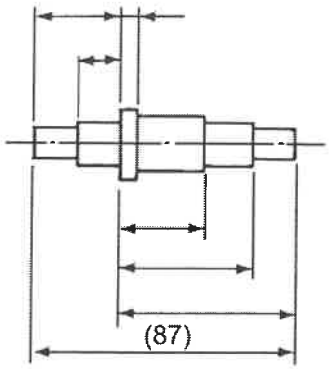


Figure 47 — Overall length added as an auxiliary dimension

9.6 Toleranced dimensions

9.6.1 General

As it is impossible to manufacture components to exact sizes, tolerances are used to define the maximum and minimum limits of size that are acceptable. The magnitude of the tolerance will vary with the class of work. In fine precision work, the tolerances will be of a different order from that of the tolerances used on large castings. Tolerances should be chosen with due regard to performance, possible difficulties in manufacture, inspection and assembly, and should be as great as satisfactory functioning will permit.

Except where the application of normal workshop techniques can be relied upon to achieve the required accuracy of form, geometric (form) tolerances (see SANS 10111-2) should be for all dimensions critical to function and interchangeability. Geometric tolerances, when applied, take precedence over the size tolerance, i.e. when a component complies with a size tolerance but fails to comply with the geometric tolerance given, the component is defective. **Amdt 1**

9.6.2 Application of tolerances

Tolerances should be applied to dimensions in the following circumstances:

a) When the dimensions are critical to function or interchangeability, and it is doubtful whether ordinary or established workshop techniques and equipment can be relied upon to achieve a satisfactory standard of accuracy; and

b) when it is desirable to indicate that unusually wide variations are permissible.

9.6.3 Specification of tolerances

Every dimension inscribed on a drawing should, in principle, be associated with a tolerance, which is normally indicated as in (b) below. However, it is acceptable to give general tolerances as in (a) below and, where necessary, to give tolerances to individual dimensions only.

a) **General tolerances**. When appropriate, general notes may be used to state allowable tolerances. Examples of general tolerance notes are given in table 6.

Table 6 — Examples of general tolerance notes

Tolerance (Except where otherwise stated): ± 0,0X

Tolerances (except where otherwise stated) on dimensions:	
Size	Tolerance
Up to X	± 0,X
Over X up to XX	± 0,X
Over XX up to XXX	± 0,X
Over XXX	± 0,X
All angles	± X°

Tolerance on cast thicknesses: ± X %

For tolerance on forging dimensions, see XX XXXX

b) **Tolerancing of individual dimensions**. One of the following methods should be used to indicate tolerance on individual linear and angular dimensions:

1) **Method A**. Both limits of size should be given above the dimension line, the upper limit being placed above the lower limit (see figure 48).

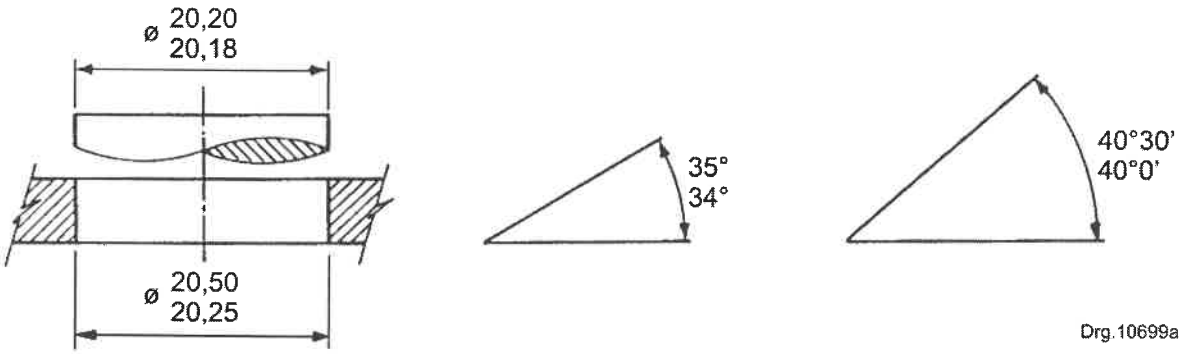


Figure 48 — Tolerancing by specifying both limits of size

2) **Method B**. The required size and limits of tolerance above and below that size should be given (see figure 49).

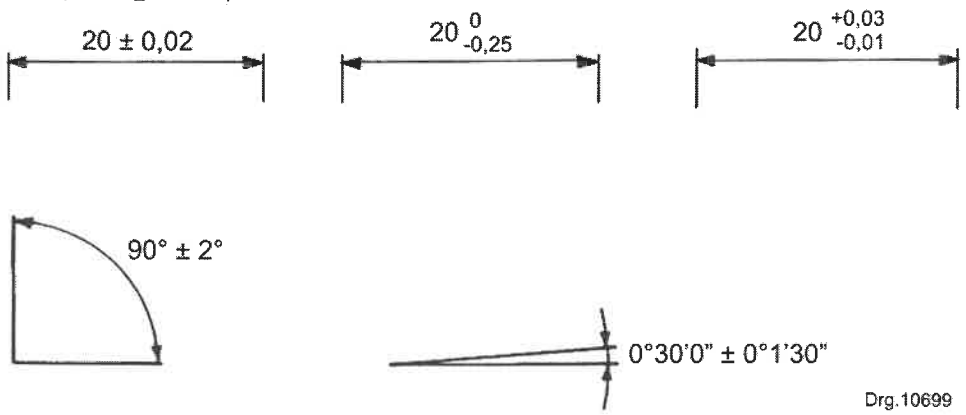


Figure 49 — Tolerancing by specifying size with limits of tolerance above and below that size

c) **Limits of fit**. Where fits taken from SANS 286-1 or ISO 1829 are used, the appropriate symbols should be given, as in the following examples: **Amdt 2**

For shafts:	40	$^{-0,025}_{-0,050}$	(f7) or	39,975 39,950	(f7)
For holes:	40	$^{+0,039}_{0}$	(H8) or	40,039 40,00	(H8)

Where these dimensions become numerous, the values of the designations need not be indicated on the dimension but may appear in tabulated form on the drawing.

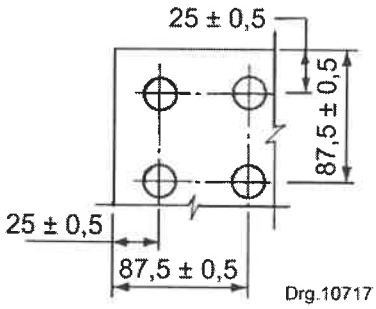
9.6.4 Single limits of size

The abbreviations "max." and "min." should be used, as appropriate, to specify a single limit of size of a dimension:

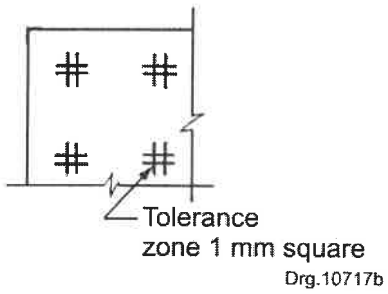
e.g. R 0,02 max. (for the maximum radius permitted);

Length of full thread 17,5 min. (for the minimum length of full thread permitted).

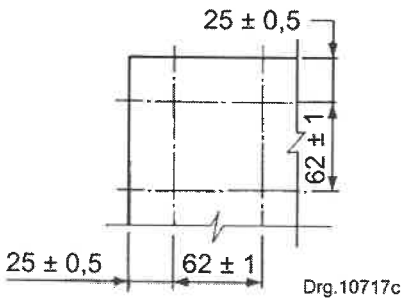
In these cases, any general tolerance note on the drawing does not apply.



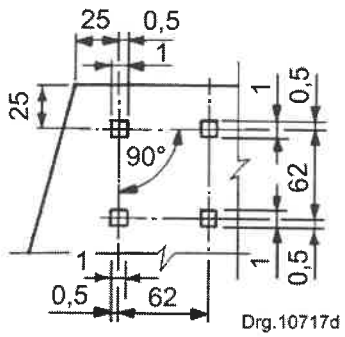
(a) **Drawing detail**



(b) **Interpretation of drawing detail**



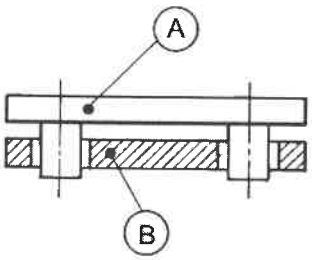
(c) **Tolerance form on square component**



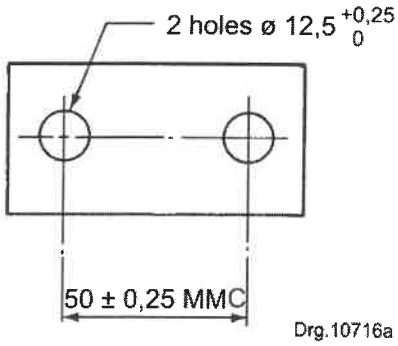
(d) **Square tolerance form, irrespective of shape of outline of component**

Figure 52 — Interpretation of toleranced centre distances

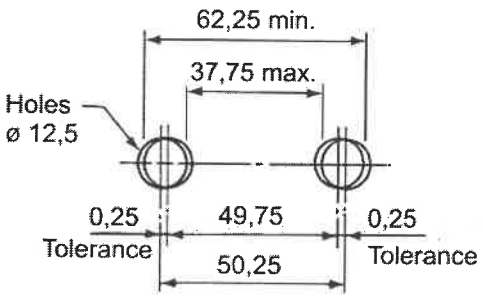
Normally, the tolerance on a centre distance should be observed independently of the actual finished sizes of the features concerned. However, in many applications (see figure 53), the stated tolerance on the centre distance may be exceeded if the features are not at their maximum material limit of size (because of the increased clearance between the mating features). In such a case, the toleranced dimension of a centre distance should be marked with the letters MMC (maximum material condition) as in figure 53(b) to indicate that the stated tolerance on the centre distance should be observed if the features are at their maximum material limit, but may be increased when the features are finished away from their maximum material limits in the direction of minimum material limits. The centre distances can then be checked by a simple gauge, similar to part A in figure 53(a), instead of by direct measurements.



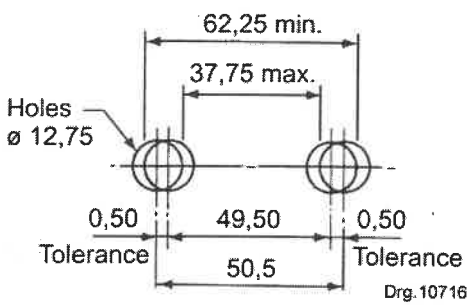
(a) Assembly



(b) Detail of component B



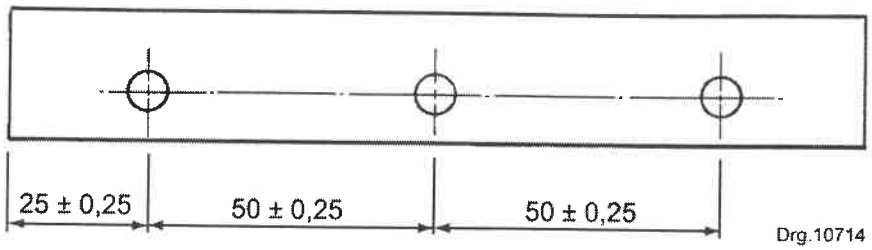
(c) Tolerance diagram for maximum material condition



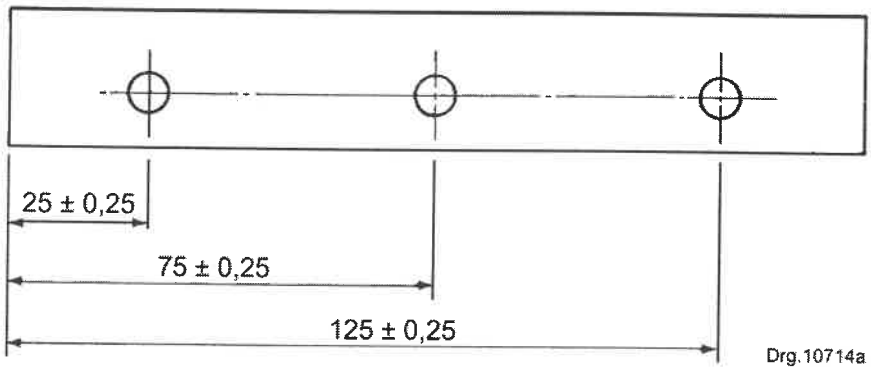
(d) Tolerance diagram for minimum material condition

Figure 53 — Interpretation of toleranced centre distances in relation to maximum material condition

Either of the methods shown in figure 54 may be used to express a string of toleranced centre distances. In the chain dimensioning method (see figure 54(a)), there is an accumulation of tolerances between the end of the plate and the second and third holes, resulting in a tolerance of ± 0,75 on the position of the third hole, and a tolerance of ± 0,50 on the dimension between the first hole and the third hole. In the datum line dimensioning method (see figure 54(b)), this is avoided.



(a) Chain dimensioning



(b) Datum line dimensioning

Figure 54 — Comparison of chain and datum line methods for expressing toleranced centre distances

The method of toleranced centre distances is suitable for defining the distance between two features (e.g. the position of a hole relative to a flat surface or the distance between a pair of holes). Typical illustrations of this are shown in figure 55.

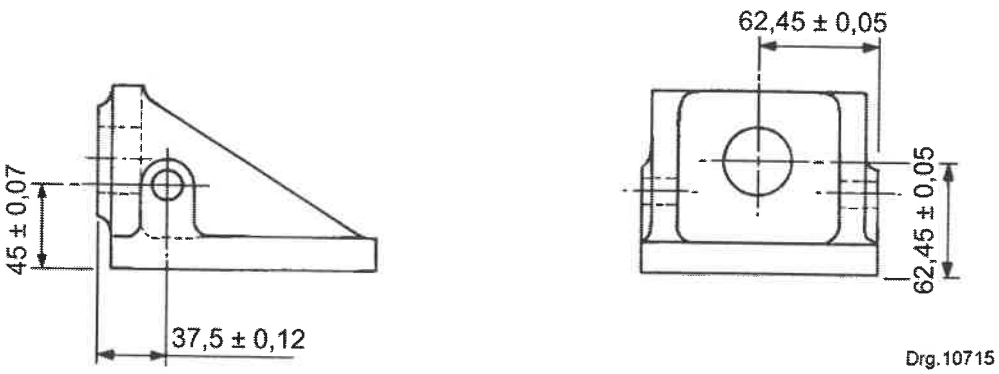


Figure 55 — Dimensioning positions by toleranced centre distances

9.7 Methods of dimensioning common features

9.7.1 Diameters

a) **Symbol**. The symbol Ø should be used to dimension a diameter and should be placed before the relevant dimension (e.g. Ø 125) (see figure 56).

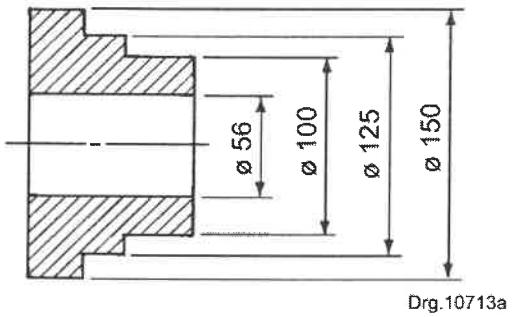


Figure 56 — Dimensioning of diameters

b) **Arrangement**. Dimensions of diameters should be placed on the most appropriate view to ensure clarity (see figure 57).

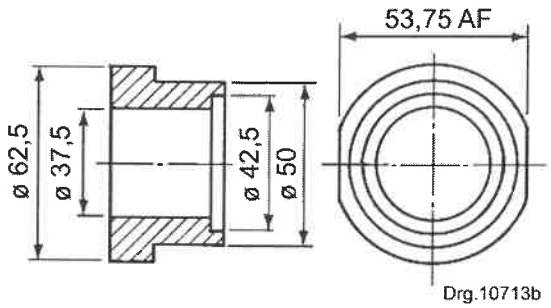


Figure 57 — Arrangement of dimensioning of diameters

c) **Dimensions outside component**. Dimensions of diameters may be placed outside the component (see figure 58).

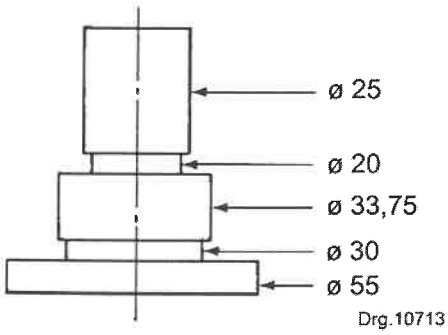
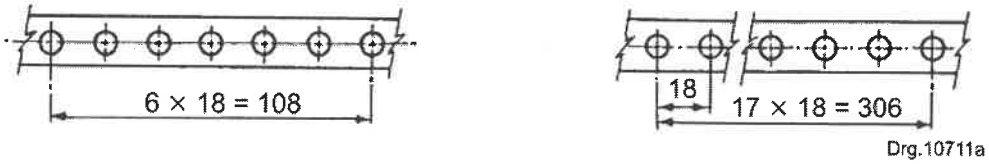


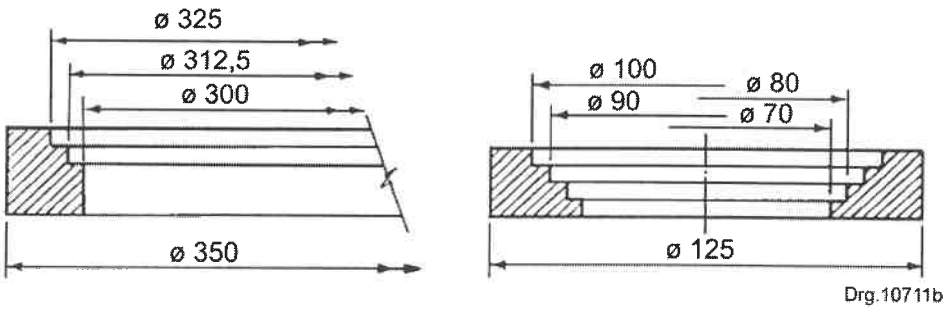
Figure 58 — Dimensioning of diameters placed outside component

d) **Dimensioning where space is restricted**. Where space is restricted, one of the methods shown in figure 59 may be used.



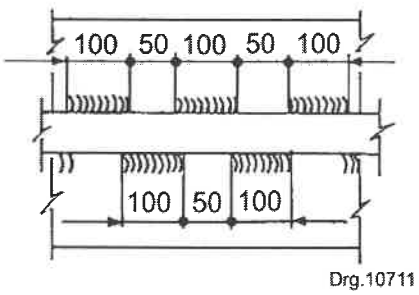
(a) (b)

Where equidistant or regularly arranged elements appear on a drawing, the method shown in (a) may be used for simplicity. If there is any possibility of confusion between the pitch and the number of pitches, one pitch should be dimensioned as in (b).



(c) (d)

Dimensioning of diameters where space is restricted

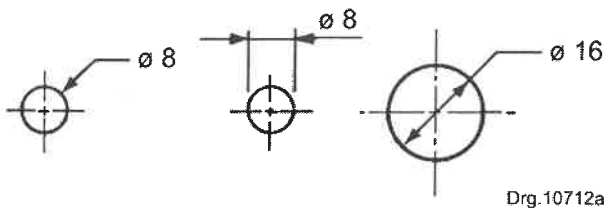


(e)

Where there is little space for arrow heads, dots may be used.

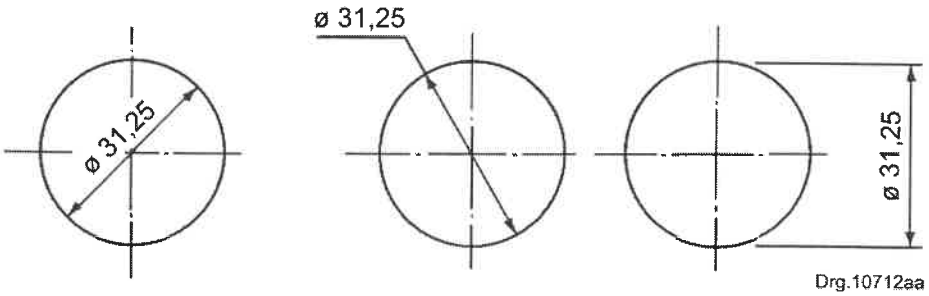
Figure 59 — Dimensioning where space is restricted

e) **Circles**. One of the methods shown in figure 60 should be used to dimension the diameter of a circle.



(a) (b) (c)

NOTE Leader to be in line with centre.



(d) (e) (f)

Figure 60 — Dimensioning the diameters of circles

f) **Spheres**. The method shown in figure 61 should be used to dimension the diameter of a sphere.

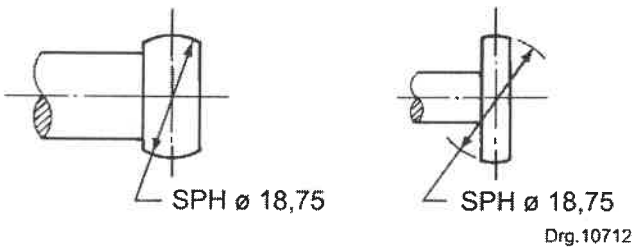


Figure 61 — Dimensioning the diameter of a sphere

9.7.2 Radii

a) **General**. The dimension line for a radius should be drawn to pass through the centre of (or to be in line with the centre of) the arc, and an arrowhead should be placed on the dimension line where it touches the arc.

b) **Abbreviation**. The abbreviation "R" should be placed before the dimension, e.g. R 5,02.

c) **Radii of arcs**. One of the methods shown in figure 62 should be used to dimension the radius of an arc. The centre of the arc need not be located.

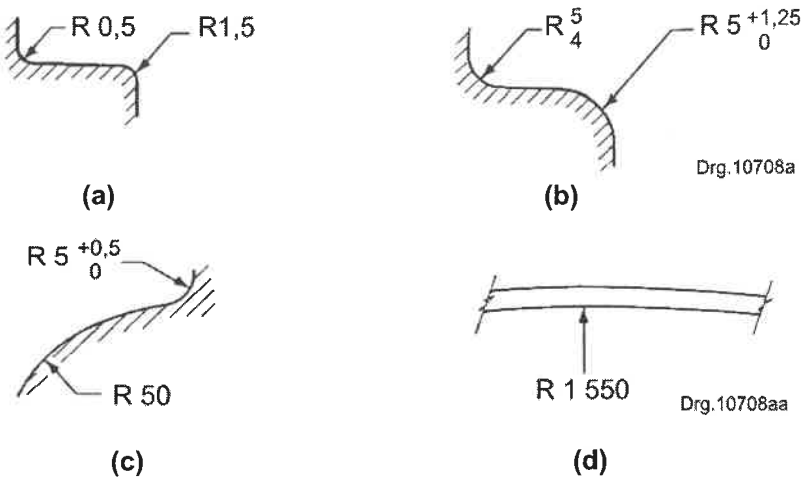


Figure 62 — Dimensioning the radius of an arc

d) **Locating inconveniently placed centres**. When it is necessary to locate the centre of an arc that cannot be shown in its true position, one of the methods shown in figure 63 should be used.

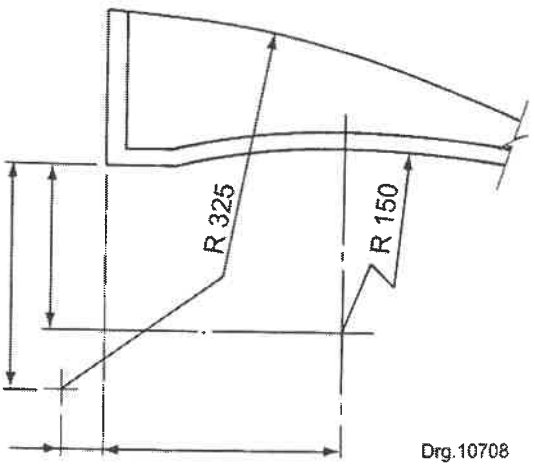


Figure 63 — Locating an inconveniently placed centre

e) **Radius of spherical surface**. One of the methods shown in figure 64 should be used to dimension the radius of a spherical surface.

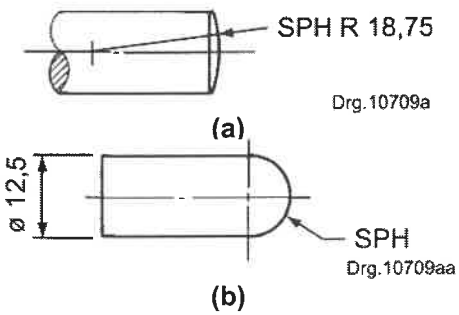


Figure 64 — Dimensioning the radius of a spherical surface

f) **Radii of curves other than circles and spheres**. One of the methods shown in figures 65 and 66 should be used to dimension a curved line other than a circle or a sphere.

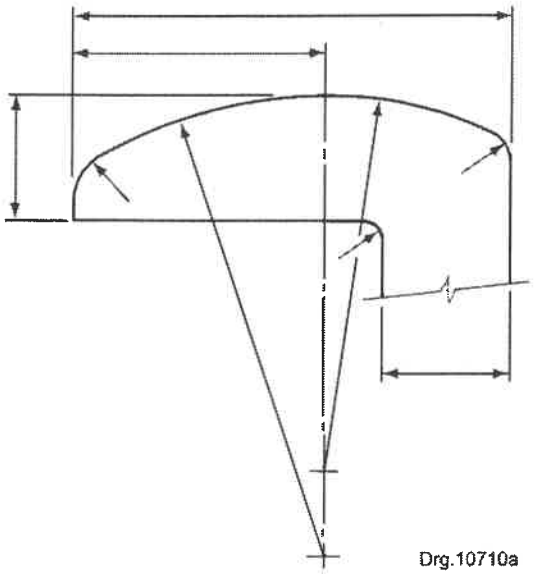


Figure 65 — Dimensioning of a curved line by means of radii

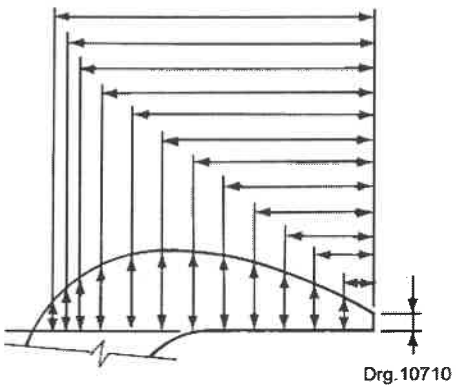


Figure 66 — Dimensioning of a curved line by means of co-ordinates

9.7.3 Holes

a) **Size**. One of the methods shown in figure 67 should be used to dimension holes. Suitable methods of production (e.g. drill, punch, ream, core) may be specified, where appropriate. The depth of a drilled hole, when stated in note form, refers to the depth of the cylindrical hole, and not to the point of the drill.

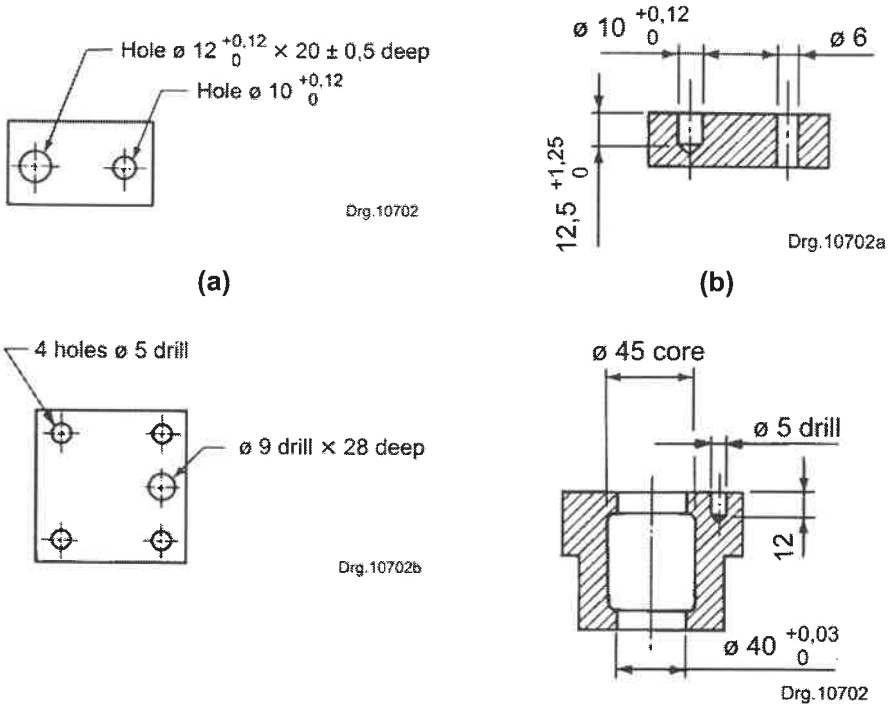
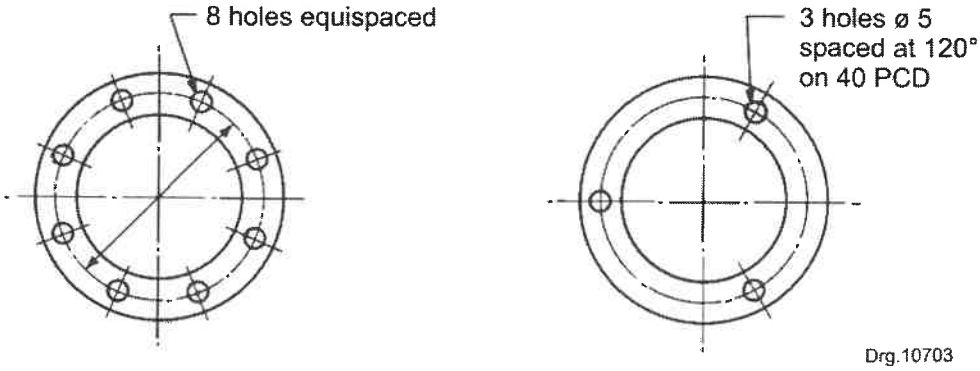
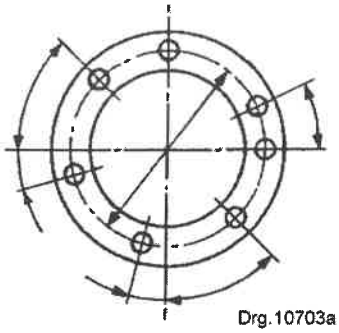


Figure 67 — Dimensioning of holes

b) **Positioning**. Holes may be positioned by dimensioning them on pitch circles as shown in figure 68, or by giving the rectangular co-ordinates as shown in figure 69. The pitch circle diameter (PCD) may, for purposes of clarity, be given in a note instead of on the drawing.

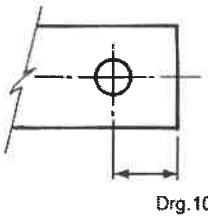


(a) Holes equally spaced

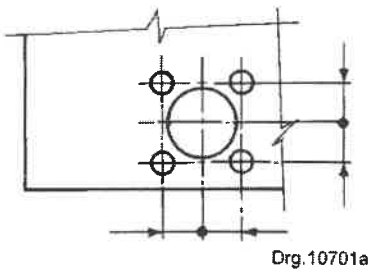


(b) Holes equally spaced. Alternatively, several or all of the angular dimensions may be given from one centre line

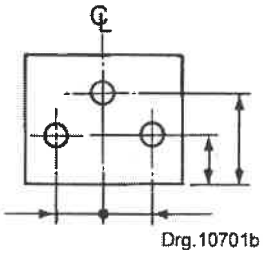
Figure 68 — Positioning of holes by angular dimensioning on a pitch circle



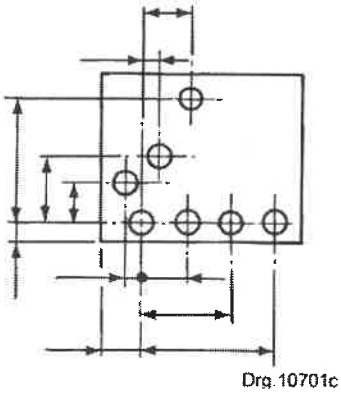
(a) Symmetry of hole with edges of plate implies



(b) Symmetry of holes defined

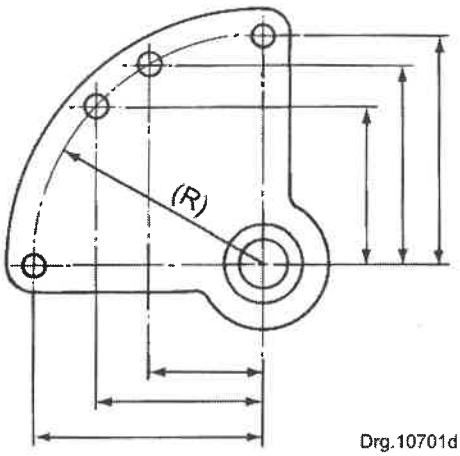


(c) Relation to lower edge important



(d) Use of co-ordinates

Figure 69 — Positioning of holes by co-ordinates



(e) Use of co-ordinates for holes lying on a pitch circle, with radius as an auxiliary dimension

Figure 69 — Positioning of holes by co-ordinates (*concluded*)

9.7.4 The square symbol

The square symbol □ may be used to dimension a square section and should be placed in front of the relevant dimension (see figure 70).

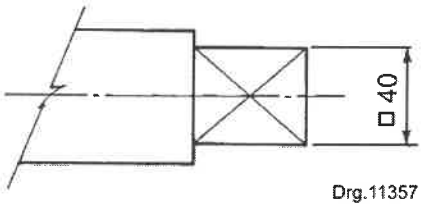


Figure 70 — The square symbol

9.7.5 The slope symbol

a) The symbol  indicates a slope and, correctly orientated, may be used to show the direction of the slope.

b) Slope is the inclination of the line representing the inclined surface of a wedge, expressed as the ratio of the differences between the heights at right angles to the base line at a specified distance apart, and that distance.

Thus slope = $\frac{H-h}{L}$ = tan β (see figure 71)

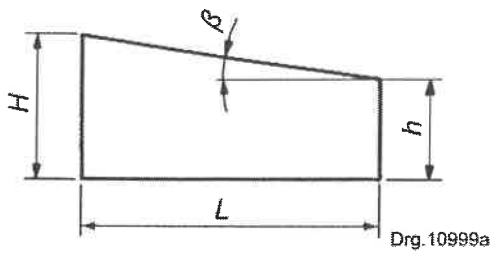
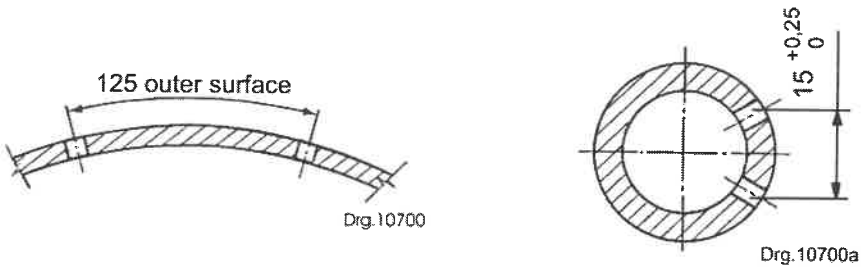


Figure 71 — Slope

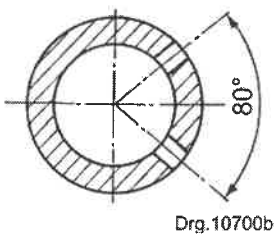
9.7.6 Curved surfaces

It should be clearly indicated on which curved surface the dimensions between holes or other features are to be measured and whether the dimensions are circumferential, chordal or angular (see figure 72).



(a) **(b)**

Linear dimensioning on curved surfaces



(c) Angular dimensioning on curved surfaces

Figure 72 — Dimensioning on curved surfaces

9.7.7 Countersinks, counterbores and spotfaces

The methods and abbreviations shown in figure 73 should be used to dimension countersinks, counterbores and spotfaces. Notes such as "Counterbore to suit M6 cheese-head screw" should not be used.

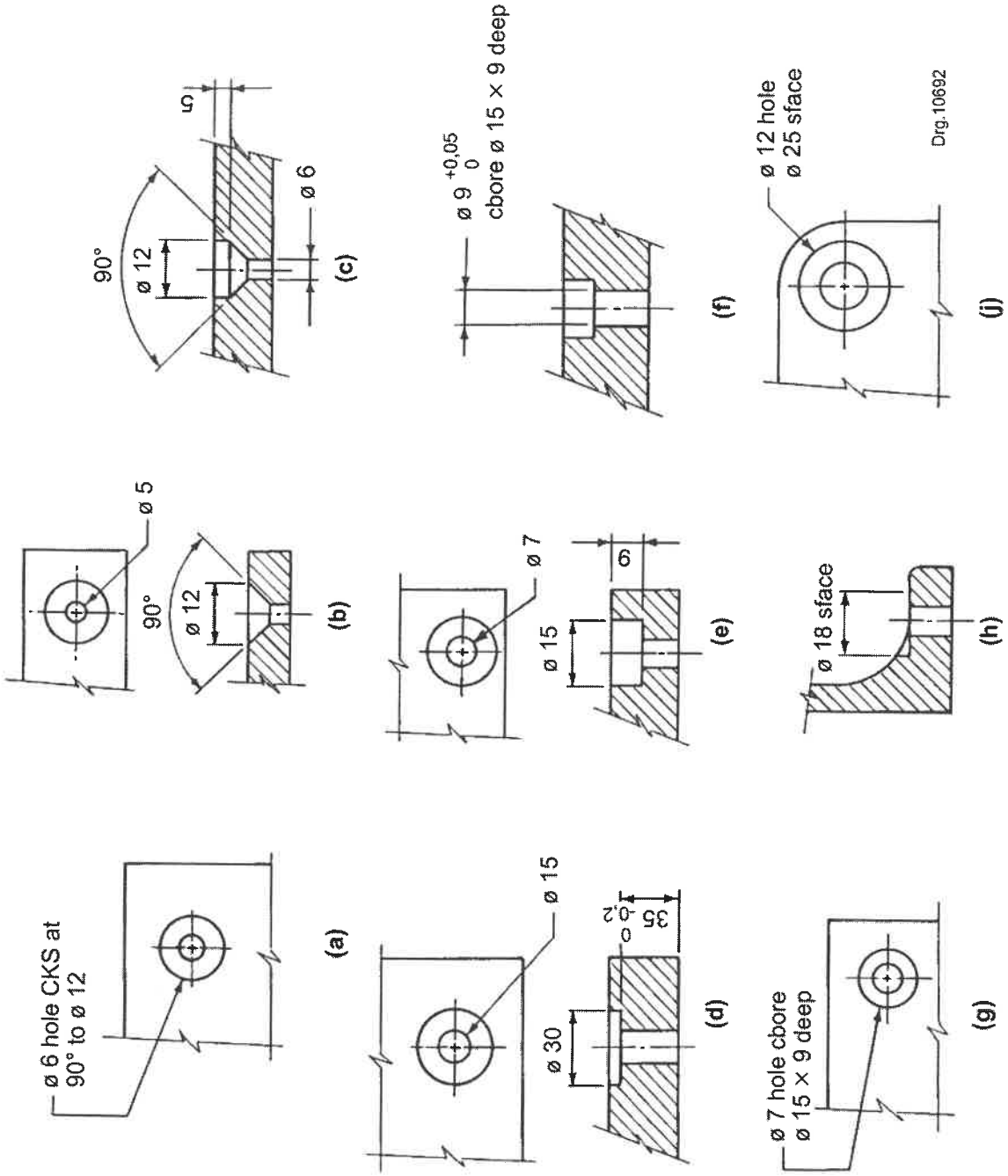


Figure 73 — Dimensioning of countersinks, counterbores and spotfaces

9.7.8 Chamfers

The methods shown in figure 74 should be used to dimension chamfers. Notes and leaders should not be used.

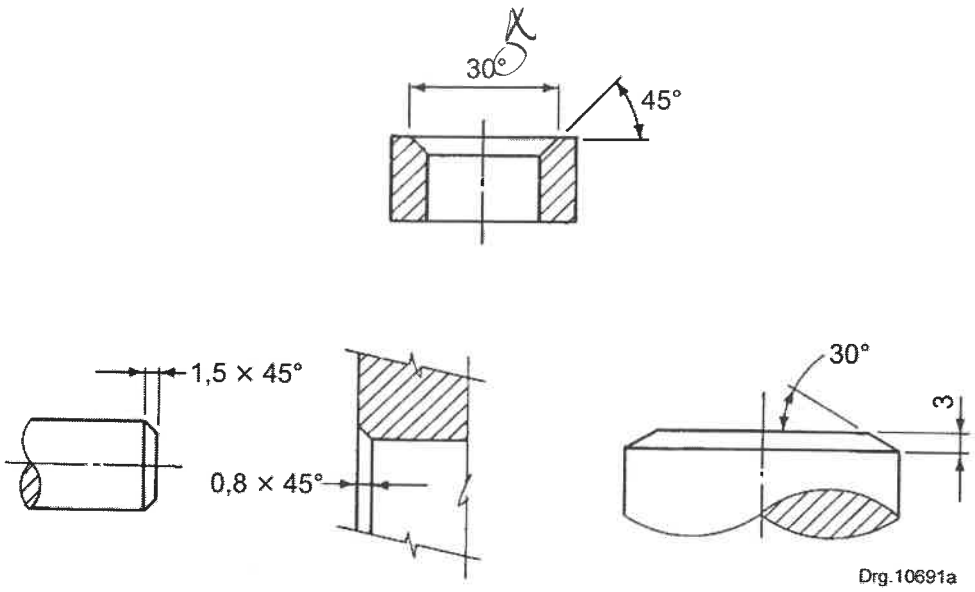


Figure 74 — Dimensioning of chamfers

9.7.9 Screw threads

a) **Designation**. Standard screw threads should be specified by the designation given in the appropriate standard.

1) ISO metric screw threads should be specified as in the following examples (see ISO 261 and BS 3643-2):

Coarse thread series: M10; M12; etc.

Fine thread series: M10 × 0,75; M12 × 1,0; etc.

NOTE The absence of the indication of pitch means that a course pitch is specified.

2) Special screw threads for which the tolerances need to be calculated should be specified by giving the major, pitch and minor diameters as shown in figure 75.

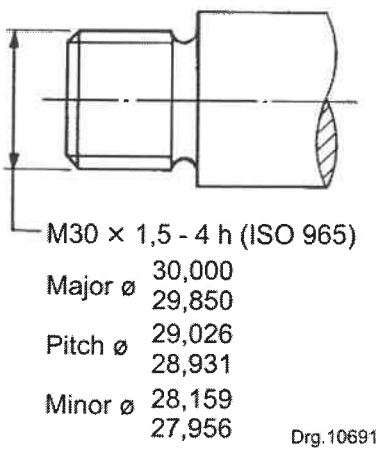


Figure 75 — Dimensioning of a special screw thread