SRI LANKA STANDARD 409 : PART 3 : 2004

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SRI LANKA STANDARD
ENGINEERING DRAWING PRACTICE
PART 3 : RECOMMENDATIONS FOR GEOMETRICAL TOLERANCING
(FIRST REVISION)

SRI LANKA STANDARDS INSTITUTION

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PART 3: RECOMMENDATIONS FOR GEOMETRICAL TOLERANCING
(FIRST REVISION)

SLS 409: Part 3: 2004

Gr. 23

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Sri Lanka Standards are subject to periodical revision in order to accommodate the progress made by industry. Suggestions for improvement will be recorded and brought to the notice of the Committees to which the revisions are entrusted.

This standard does not purport to include all the necessary provisions of a contract.

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Draft Sri Lanka Standard
ENGINEERING DRAWING PRACTICE
PART 3 : RECOMMENDATIONS FOR GEOMETRICAL TOLERANCING
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FOREWORD

This standard was approved by the Sectoral Committee on Materials, Mechanical Systems and Manufacturing Engineering and was authorized for adoption and publication as a Sri Lanka Standard by the Council of the Sri Lanka Standards Institution on 2004-12-09.

This standard is the first revision of **SLS 409** published in 1977.

For convenience of use, this revision of **SLS 409** is present in three parts as follows:

Part 1 Recommendations for general principles
Part 2 Recommendations for dimensioning and tolerancing of Size and Method of indicating surface texture
Part 3 Recommendations for geometrical tolerancing

The proven record of standards applied to engineering drawing now enables its recognition as the graphical language of communication in engineering both nationally and internationally. Drawings made to the accepted standards in one country, when based on standards published by the International Organization for Standardization (ISO) are understood and can be used around the world virtually in all countries. With this in mind it was recognized and accepted to be important as a policy for this revision that particular attention and care should be paid to the quality of content of both text and figures to ensure their clarity and ease of understanding.

During the course of this revision particular attention has been paid to developments in computer-aided drafting and it has been established that such systems are currently capable of complying with this standard. Any minor exceptions due to the limitation of a particular system would not be expected to prejudice the understanding of a drawing otherwise claimed to comply with this standard.

NOTES (ON THE PRESENTATION OF THIS STANDARD):

1. The figures in this standard are independent and each is selected solely for its simplicity and clarity to illustrate, only the text to which it relates. They are not the only possible examples and they are not intended as design examples or to be fully dimensioned working drawings but otherwise are drawn according to the basic recommendations of this standard.

2. Linear dimensions shown in the figures are in millimeters.

3. Numerical values of dimensions and tolerances given in the figures throughout are arbitrarily chosen to assist in illustrating the point under consideration; they are typical and are not given as recommendations.

4. This standard recognizes both the first and third angle projection methods as having equal status but the first angle projection method is more frequently used.

*5. Due to the limitations of size of the figures in this standard, the sizes of arrowheads may not conform to the recommendations of **6.4** of **SLS 409 : Part 1: 2004.***

In the preparation of this standard valuable assistance derived from the relevant publication of the International Organization for Standardization, and British Standards Institution are gratefully acknowledged.

1 SCOPE

This part of **SLS 409** gives recommendations for the general principles, definitions and the methods of indication of geometrical tolerances on engineering drawings.

NOTE: *Civil structural engineering and construction service drawings are excluded. The special discipline aspects of naval architecture and aeronautical lofting are not included.*

2 REFERENCES

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

BS 308 Engineering Drawing Practice
Part 3-,– Recommendation for Geometrical Tolerancing

SLS 409 Engineering Drawing Practice
Part 1 : Recommendations for general principles-
Part 2 : Recommendations for dimensioning and tolerancing of Size and Method of indicating surface texture

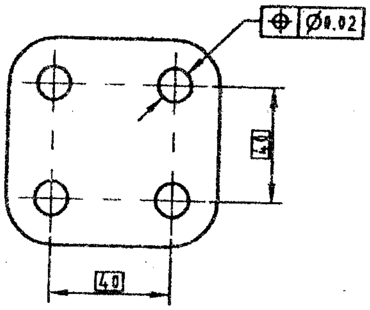
3 DEFINITIONS

For the purpose of this part of the standard, the definitions given in SLS **409 Part 2** shall apply together with those given below:

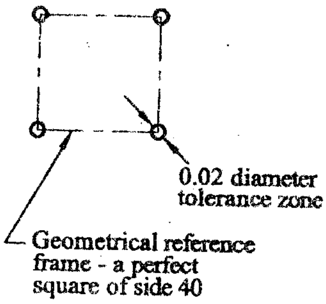
3.1 geometrical tolerance: The system used to control deviations in geometry.

3.2 geometrical reference frame: An interpretive diagram constructed from dimensions, which define the theoretically exact positional relationships between the features in any one group (see Figure 1).

NOTE : *Whilst a geometrical reference frame is not intended to appear on a drawing it may aid the interpretation of complex positional tolerance requirements.*



(a) Drawing indication



(b) Geometrical reference frame and tolerance diagram

FIGURE 1 - Example of geometrical reference frame

3.3 datum: A theoretically exact geometric reference such as an axis, plane, straight line, etc., to which tolerance features are related.

NOTE : *A datum is established by one or more datum features of a part.*

3.4 datum feature: A real feature of a part (such as an edge, or a flat or a cylindrical surface), which is used to establish the location of a datum.

NOTE: *As datum features are subject to manufacturing variations, it may be necessary to specify geometrical tolerances for them.*

3.5 datum system: A group of two or more datums used as a reference for a toleranced feature.

3.6 simulated datum: A real surface of adequately precise form such as a surface plate, bearing, mandrel, etc. or a surface within a precise fixture, piece of equipment or machine which, when placed in contact with a datum feature, establishes that datum.

NOTE: *A simulated datum is used as the practical embodiment of the specified datum during manufacture and inspection and is considered to be perfect.*

3.7 datum target: A point, line or limited area of defined size and location specified on a datum feature to ensure repeatable contact with a simulated datum.

3.8 tolerance zone: Area or space on which a given tolerance remain applicable

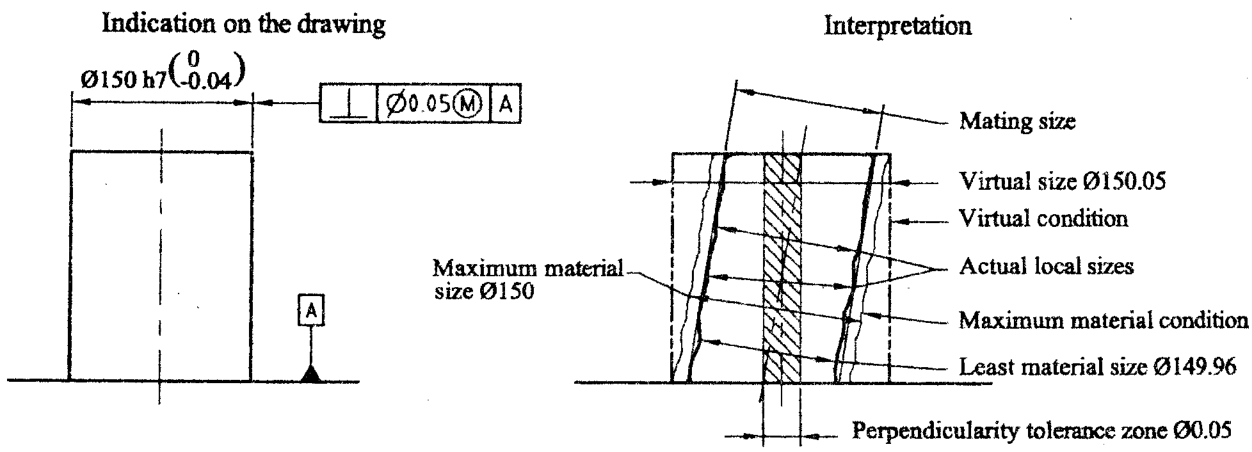
3.9 actual local size: An actual two-point measurement of a dimensioned feature.

3.10 mating size for an external feature: The dimensions of the smallest perfect feature which can be circumscribed about the feature so that it just contacts the surface at the highest points.

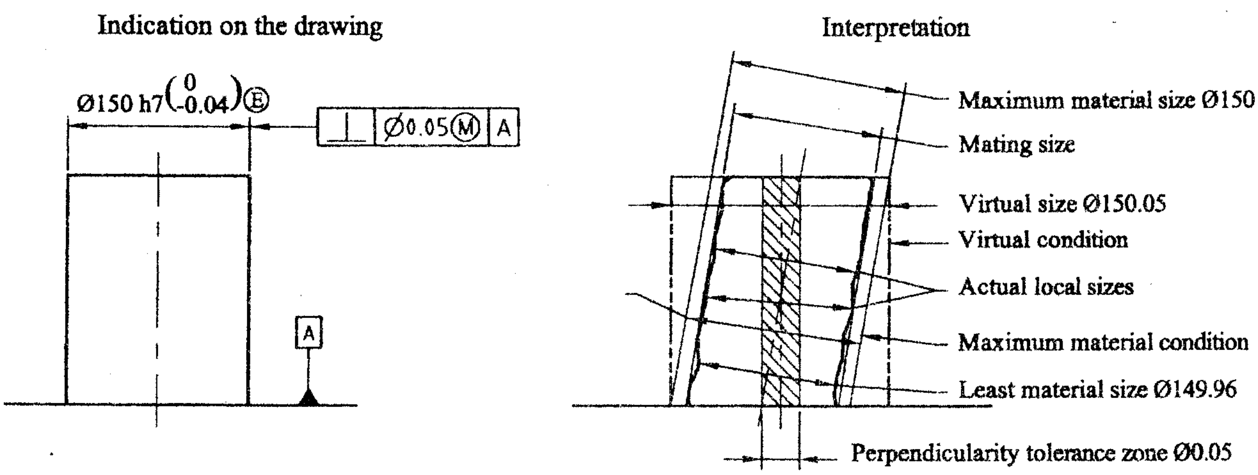
NOTE: *For an example the size of the smallest cylinder of perfect form or the smallest distance between two parallel planes of perfect form which just contacts the highest point(s) of the actual surface (s) (see Figure 2)*

3.11 mating size for an internal feature: The dimension of the largest perfect feature, which can be inscribed within the feature so that it just contacts the surface at the highest points.

NOTE: *For example, the size of the largest cylinder of perfect form or the largest distance between two parallel planes of perfect form which just contacts the highest point(s) of the actual surface.*



(b) Dimensioning in accordance with the independance principle



(b) Dimensioning in accordance with the envelope principle

FIGURE 2 - The maximum material principle illustration of terms

3.12 maximum material condition (MMC): The state of the considered feature wherein it is everywhere at that limit of size where the material of the feature is at its maximum (see Figure 2)

3.13 maximum material size (MMS): The dimension defining the maximum permitted size of a male feature, e.g. maximum shaft diameter, and the minimum permitted size of a female feature, e.g. minimum hole size.

3.14 least material condition (LMC): The state of the considered feature in which the feature is everywhere at that limit of size where the material of this feature is at its minimum, e.g. maximum hole diameter and minimum shaft diameter.

3.15 least material size (LMS): The dimension defining the minimum permitted size of a male feature, eg. minimum shaft diameter, and the maximum permitted size of a female feature, eg. maximum hole size.

3.16 virtual condition: The limiting boundary of perfect form generated by the collective effects of the specified maximum material limit of size of a feature and any applicable geometrical tolerances.

NOTE: *When the maximum material principle is applied, only those geometrical tolerances followed by the symbol Ⓜ are to be taken into account when determining the virtual condition (see Figure 2).*

3.17 virtual size: The size of the virtual condition

3.18 least material virtual condition (LMVC): Boundary of perfect form and of least material virtual size

3.19 least material virtual size (LMVS): Generated by the collective effect of the least material size (LMS) and the geometrical tolerance followed by the symbol (L).

NOTE :

For shafts : LMVS = LMS – geometrical tolerance
For holes : LMVS = LMS + geometrical tolerance

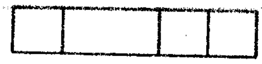
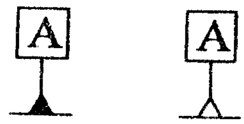
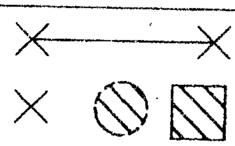
4 SYMBOLS, PROPORTIONS AND DIMENSIONS

4.1 Symbols to indicate characteristics are given in Table 1 and the use of these symbols are given in the relevant tables.

TABLE 1 - Symbols for toleranced characteristics and symbols that indicate identity and quality

Features and type of tolerance (1)		Toleranced characteristic (2)	Symbol (3)	Height of symbol (4)	Reference (5)
Single feature	Form tolerance	Straightness	—	d	Item 1 of Table 2
		Flatness	▱	10d	Item 2 of Table 2
		Circularity *	○	14d	Item 3 of Table 2
		Cylindricity	⌭	14d, and 8d for circle	Item 4 of Table 2
Single or related features		Profile of any line **	⌒	7d	Item 5 of Table 2
		Profile of any surface **	⌓	7d	Item 6 of Table 2
related features	Orientation tolerance	Parallelism	//	14d	Item 7 of Table 2
		Perpendicularity †	⊥	14d	Item 8 of Table 2
		Angularity	∠	14d	Item 9 of Table 2
	Location tolerance	Position	⌖	8d and 8d for circle	Item 10 of Table 2
		Concentricity and coaxially ††	◎	14d and 8d for inner circle	Item 11 of Table 2
		Symmetry	⌯	9d	Item 12 of Table 2
	Run-out tolerance	Circular run-out	↗	14d (60° min)	Item 13 of Table 2
		Total run-out	⌰	14d (60° min)	Item 14 of Table 2

TABLE 1 - (Concluded)

Description (1)		Symbol (2)	Height of symbol (3)	Reference (4)
Tolerance frame			20d	Clause 5
Tolerance feature indication	Direct		d	Clause 6
	Identification by letter			Clause 8.5
Datum feature indication	Direct			
	Identification by letter			
Theoretically exact dimension		50	20d Square	Clause 10
Projected tolerance zone		Ⓟ	16d for value	Clause 11
Maximum material condition qualification		Ⓜ	16d and 10d for value	
Envelope requirement		Ⓔ	16d and 10d for value	
Datum target frame			40d	
Datum target indications				

* Known also as roundness.

** A profile may be related to datum when it is necessary to control position in additional to form.

† Perpendicularity is synonymous with normal and is also known as squareness.

†† Concenrticity as the state of having the same center coaxility is the state having same axis.

NOTE: *The height of symbols are based on the selected lettering line thickness (d), which in turn is related to the height of lettering selected for drawing.*
*The height of lettering should be 10 d (Refer 6.2 of **SLS 409 Part I**)*

5. TOLERANCE FRAME

5.1 A tolerance frame is rectangular symbol which contains indications that define the geometrical tolerance for a feature (see Figure 3 **(a)**,3**(b)** and 3**(c)**) the frame should be divided into compartments, containing from left to right :

i) the symbol for the characteristic to be toleranced;
ii) the tolerance value in the unit used for linear dimensions; this value should be preceded by the diameter symbol if the tolerance zone is circular or cylindrical;
iii) the letter or letters identifying the datum feature or features, where appropriate.

5.2 Other information concerning the toleranced feature should be placed above the tolerance frame as in Figure 3**(d)**, but information qualifying the form of the feature within the tolerance zone should be placed after the tolerance frame as in Figure 3**(e)**.

5.3 When it is necessary to specify more than one toleranced characteristic for a feature, the tolerance specifications should be positioned as shown in Figure 3**(f)**. Datum (Figure 3**(g)**), toleranced characteristics (Figure 3**(h)**) and tolerance values (Figure 3**(i)**) which are common to two or more combined tolerance frames need be stated only once.

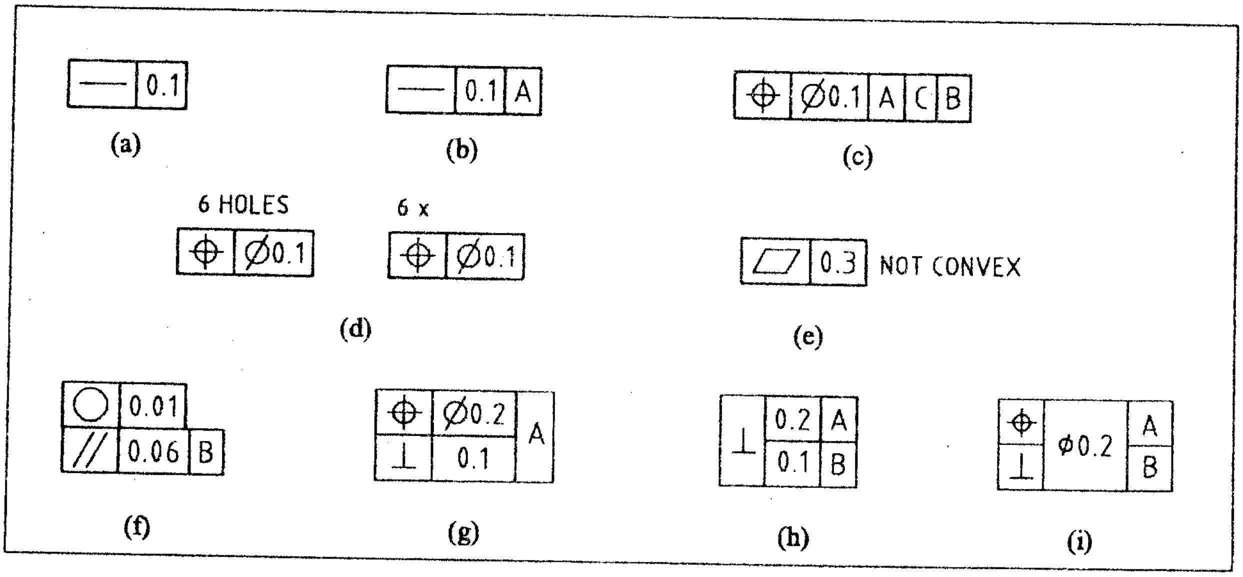


FIGURE 3 - Example of tolerance frames

6 TOLERANCED FEATURES

The tolerance frame should be connected to the toleranced feature by a leader line, which, in general, should be drawn in a direction perpendicular to the toleranced feature. At the toleranced feature, the leader line should be terminated by an arrowhead as given below :

i) when the tolerance refer to the outline itself or to the surface represented by the outline, the arrowhead should be terminated on the outline of the

i) when the tolerance refer to the outline itself or to the surface represented by the outline, the arrowhead should be terminated on the outline of the feature or an extension of the outline, but clearly separated from the dimension line as shown in (Figure **4(a)** and **(b)**).

ii) when the tolerance refer to the axis or median plane of the feature dimensioned, the arrowhead should be terminated on an extension of the dimension line as shown in Figure **4(c), (d) and (e).**

iii) when the tolerance refer to a common axis or median plane of all features lying on that axis or median plane, the arrowhead should be terminated on the axis or median plane as shown in Figure **4 (f), 4 (g), 4 (h), 4 (i).**

NOTES

1 *Whether a tolerance should be applied to the counter of a cylindrical or geometrical feature or to its axis or medium plane respectively depends on the functional requirements.*

2. *Figures 4(c) and (f) are alternative methods of expressing the same requirement on a single feature part.*

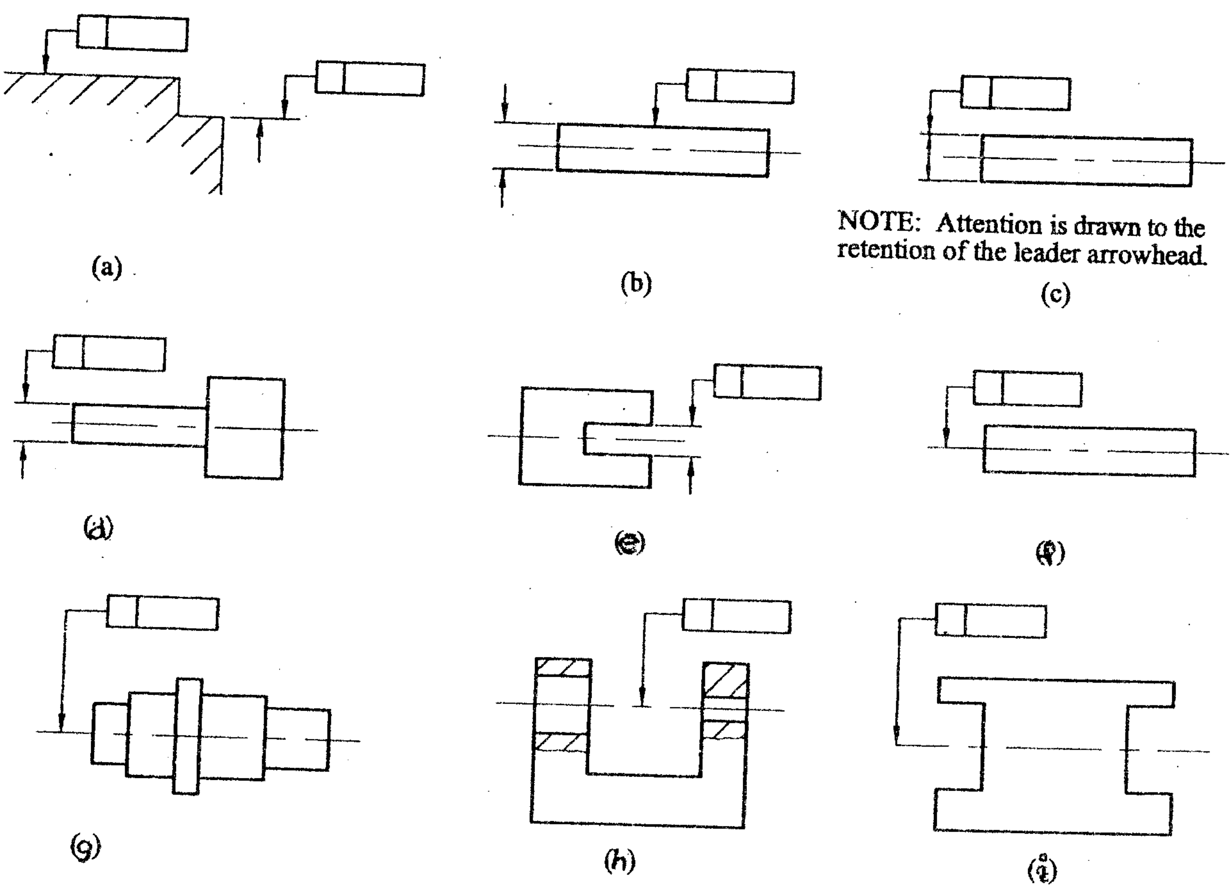


FIGURE 4 - Position of leader line

7 INDICATION OF DATUM

7.1 Indication of datum and datum features

A datum should be indicated by an equilateral triangular symbol (see Table 1 and Figure 5)

The datum should be identified by a capital letter enclosed in a frame connected to a datum symbol (see Table 1). When a toleranced feature is related to a datum, the same letter, which defines feature is related to a datum, the same letter, which defines the datum, should be repeated in the tolerance frame. A different letter should be sued for each datum identification.

NOTE: *Where there is a likelihood of confusion with the numerals 0 and 1 and the symbols (M) (P) and (E) the letters E , 1, 0, M, P and Q and other letters already in use for sections should be avoided.*

The datum symbols should be placed as follows:

i) On the outline of the feature or an extension of the outline (but clearly separated from any dimension line). When the datum feature is the line or surface itself. (see Figure **5(a)**);

ii) As an extension of the diameter dimension line when the datum is an axis or an extension of width dimension line when the datum is median plane (see Figure **5(b)** **(c)** and **(d)**);

iii) On the center line of the feature when the datum is one of the following

1) The common axis or median plane of two features (see Figure **5 (e)**);
2) The axis of a single feature, eg. a cylinder.

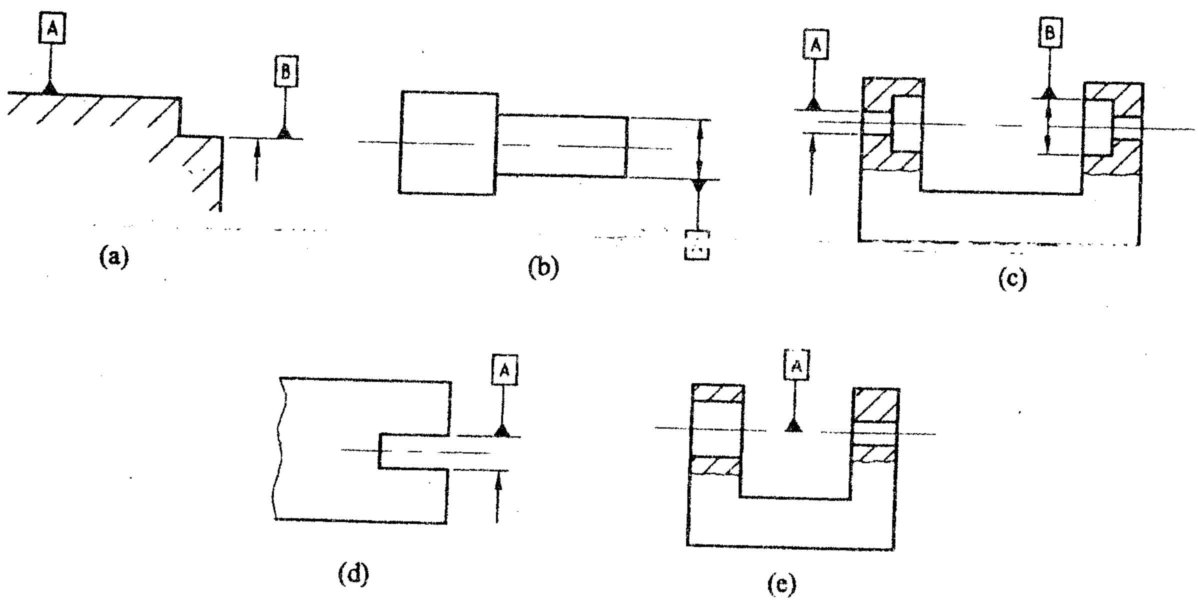
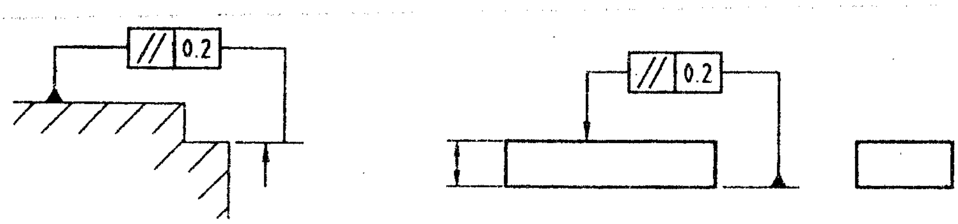


FIGURE 5 - Indication of datum feature

When the tolerance frame can be directly connected in a clear and simple manner with the datum symbol by a leader line, the datum letter may be omitted (see Figure 6).



(a) (b)

FIGURE 6 - Direct identification of datum

8. TOLERANCE ZONES

8.1 General

8.1.1 A geometrical tolerance defines the form and size of a tolerance zone within which a feature (**Clause 11 of BS 308 - Part 2 : 1990**) is to be contained.

8.1.2 Depending on the characteristic, which is to be geometrically toleranced, and the manner in which the feature is dimensioned, the tolerance zone may be one of the following

a) the area within a circle;
b) the area between two concentric circles;
c) the area between two parallel lines;
d) the space within a cylinder;
e) the space between two coaxial cylinders;
f) the space between two parallel surfaces or two parallel planes;
g) the space within a parallelepiped.

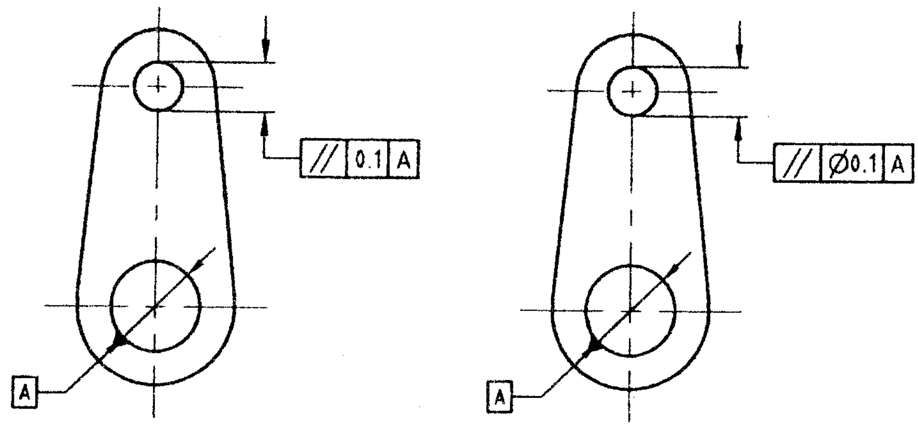
8.1.3 The tolerance should apply for the whole length or surface of the feature, unless otherwise specified.

8.1.4 The tolerance feature may be of any form or orientation within the tolerance zone, unless a more restrictive indication is given e.g. by an appeared note, Figure 3(e).

8.1.5 Geometrical tolerances which are specified for related features (see Table 1) do not limit the deviations of geometrical form of the datum feature. It may therefore be necessary to specify tolerances of form for a datum feature so as to ensure that it is sufficiently accurate for its purpose.

8.1.6 Some geometrical tolerances control deviations of more than one characteristic. For example, a parallelism or a perpendicularity tolerance applied to a flat surface also controls flatness deviations of that surface; however a flatness tolerance does not control parallelism or perpendicularity deviations. Similarly, a symmetry tolerance limits flatness and parallelism deviations and a coaxiality tolerance limits deviation from straightness of the feature to which it is applied. Therefore, when two characteristics of a feature need to be controlled, it may be sufficient to apply only one geometrical tolerance, which will keep both characteristics within the desired limits.

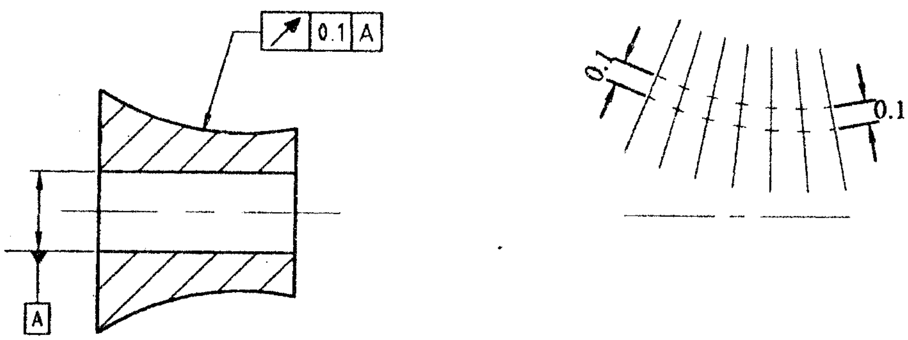
8.2 The width of the tolerance zone is indicated by the direction of the arrow of the leader line joining the tolerance frame to the feature, which is toleranced (see Figure **7(a)**), unless the tolerance value is preceeded by the diameter symbol (see Figure **7(b)**)



(a) (b)

FIGURE 7 - Tolerance zone for parallelism

8.3 The direction of the width of the tolerance zone is perpendicular to the specified profile of the toleranced feature (see Figure **8**), unless otherwise indicated.



(a) Drawing indication (b) Interpretation

FIGURE 8 - Tolerance zone for run-out

8.4 It is essential that the direction of the width of the tolerance zone is indicated when it is required to apply in a direction other than perpendicular to the specified geometry of the part (see Figure **9**).

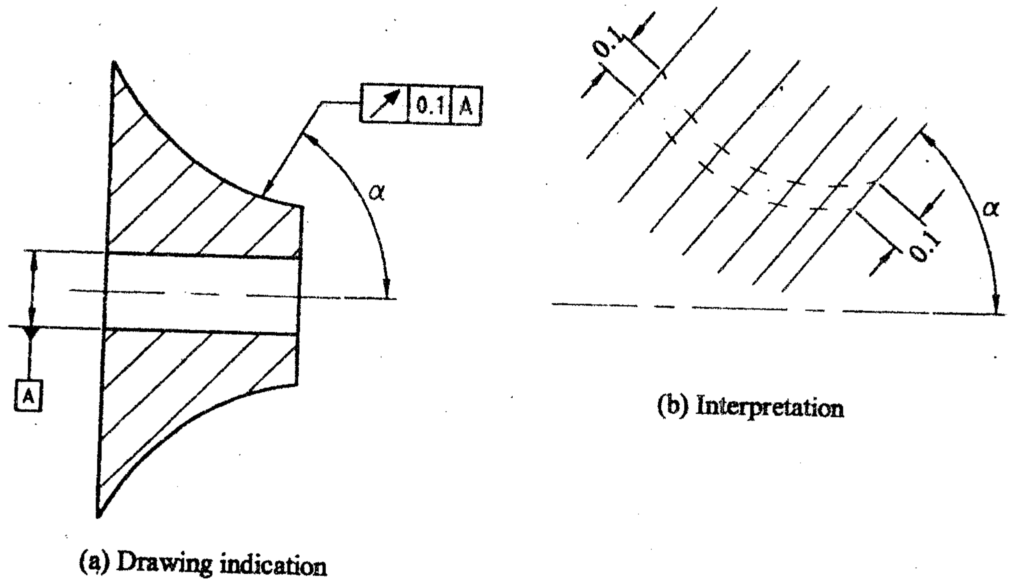


FIGURE 9 - Tolerance zone for run-out

8.5 When individual tolerance zones of the same size are applied to several separate features they may be indicated as shown in Figure **10.**

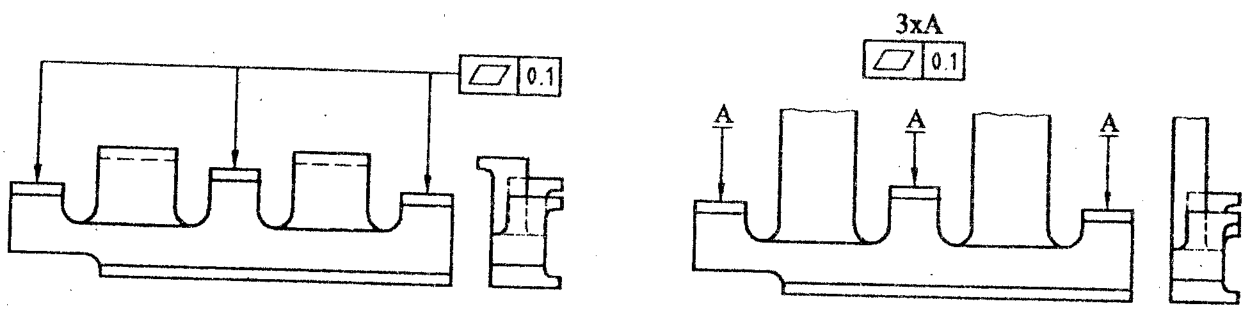


FIGURE 10 - Individual tolerance zones of the same size

8.6 When a common tolerance zone is applied to several separate features, the requirement should be indicated by the words "common zone" above the tolerance frame (see Figure **11**).

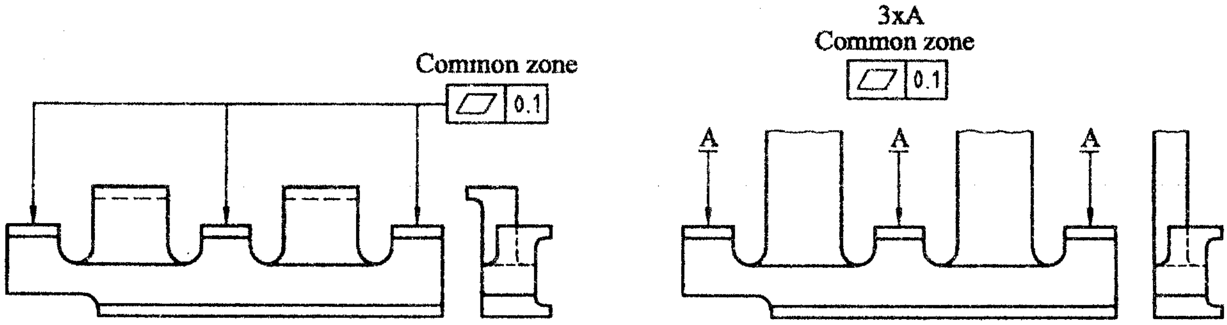


FIGURE 11 - Common tolerance zones

9 TOLERANCE APPLICABLE TO RESTRICTED LENGTHS OF FEATURES

9.1 If the tolerance is applied to a restricted length, lying anywhere, the value of this length shall be added after the tolerance value and separated from it by an oblique stroke.

In the case of a surface, the same indication is used. This means that the tolerance applies to all lines of the restricted length in any position and any direction (see Figure 12).

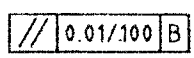


FIGURE 12 - Tolerance in a surface

9.2 If a smaller tolerance of the same type is added to the tolerance on the whole feature, but restricted over a limited length, the restrictive tolerance shall be indicated in the lower compartment (see Figure 13).

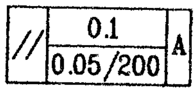


FIGURE 13 - Indication of the restrictive tolerance in the lower compartment

9.3 If the tolerance is applied to a restricted part of the feature only, this shall be dimensioned as shown in Figure **14**.

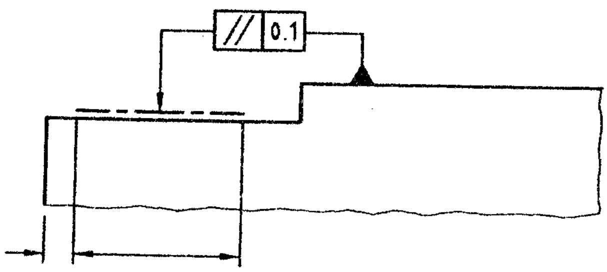


FIGURE 14 - Tolerance in a restricted part of the feature

9.4 If the tolerance is applied to a restricted part of the datum feature only, this shall be dimensioned as shown in Figure **15**.

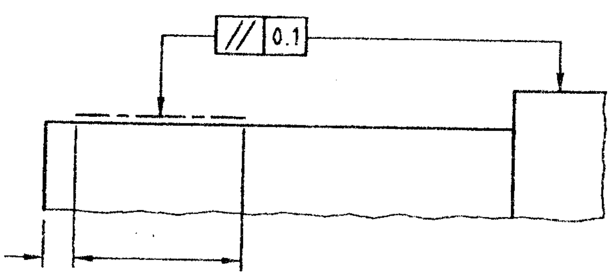


FIGURE 15 - Tolerance only at the restricted part of the datum feature

10 THEORETICALLY EXACT DIMENSION

If tolerance of position, or of profile or of angularity are prescribed for a feature, the dimensions determining the theoretically exact position, profile or angle respectively, shall not be toleranced.

These dimensions are enclosed, for example [30]. The corresponding actual dimensions of the part are subject only to the position tolerance, profile tolerance or angularity tolerance specified within the tolerance frame (see Figures 16 and 17).

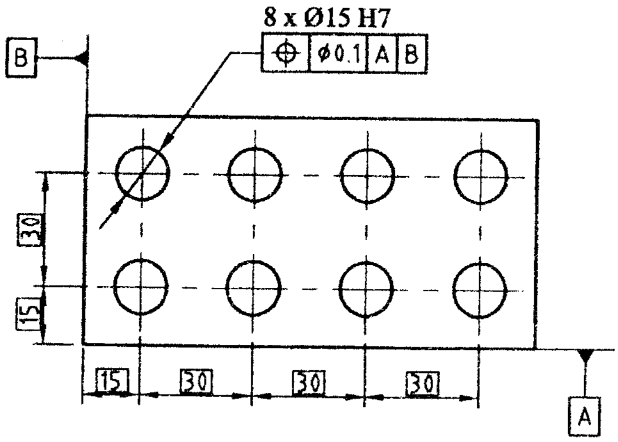


FIGURE 16 - Positional tolerance

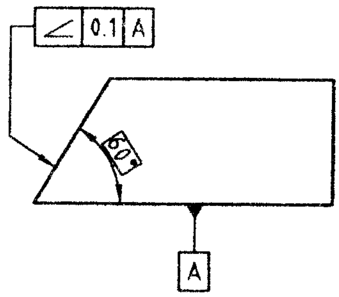


FIGURE 17 - Angularity tolerance

11 PROJECTED TOLERANCE ZONE

A cylindrical tolerance zone that limits deviation from the theoretically exact position of a hole limits perpendicularity deviations of the axis relative to the face at one end of the hole (the primary datum).

When the hole is to be used to secure a fixed fastener the maximum perpendicularity deviation of the hole axis could cause the fastener to interfere with the clearance hole in the mating part (see Figure 18). A projected tolerance zone should be specified in order to avoid such interference. The projected tolerance zone applies only to the external projection of the axis of the securing hole from the primary datum (see Figure 18).

It should be noted that is the perpendicularity deviation of the portion of the fastener passing through the clearance hole that is significant. Therefore the projected tolerance zone is specified for the axis of the hole into which the fastener is assembled. The location and perpendicularity of this hole is of importance only to the extent that it affects the projection portion of the engaging fastener.

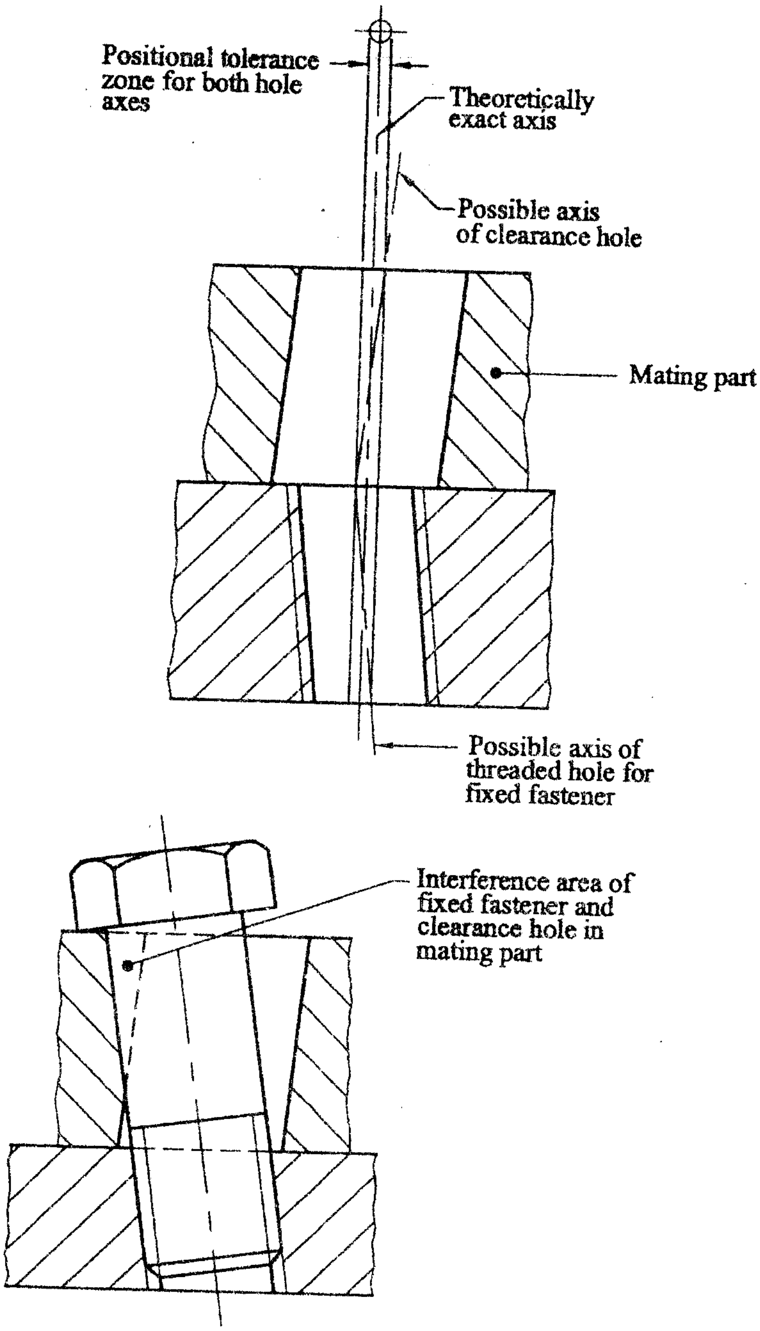
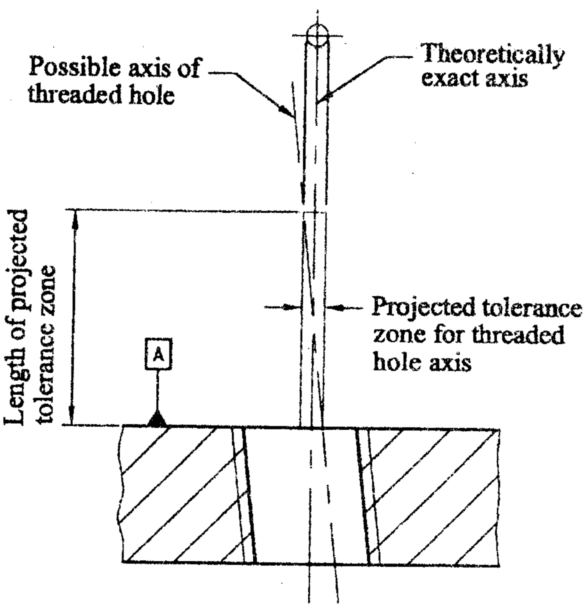
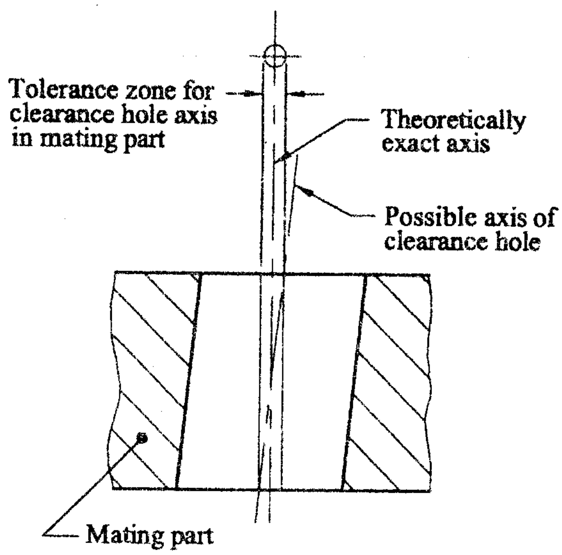


FIGURE 18 - Possible interference between parts if projected tolerance zone is not used

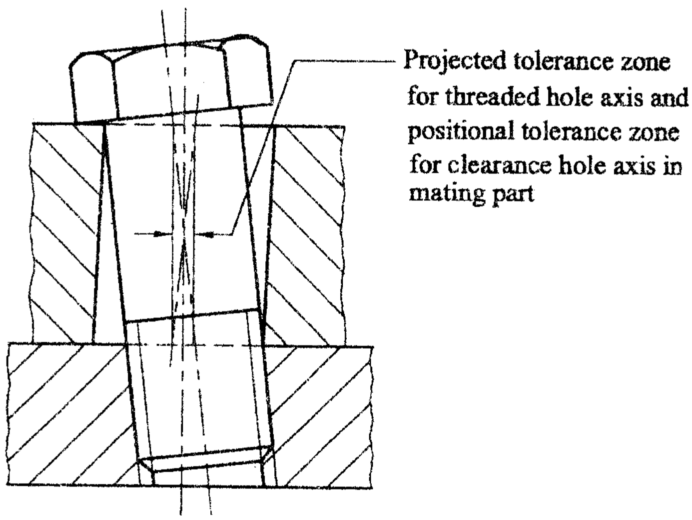


NOTE : A is the primary datum for the threaded hole

(a)



(b)



(c)

FIGURE 19 - Projected tolerance zone applied to avoid interference

11.2 Indication

A projected tolerance zone should be indicated by the symbol Ⓟ in the two positions as follows (see also Figure **20**):

a) after the value of the tolerance in the tolerance frame that applies to the feature concerned;

b) before the dimensioned length of the projected tolerance zone in an appropriate view. In this view the feature concerned should be extended to the specified length of the projected tolerance zone using type K lines (see Table **3** of **SLS 409: Part 1**).

11.3 Specified length of projected tolerance zone

The specified length of a projected tolerance zone is a minimum. Where the fixed fastener is a screw the minimum specified length is the maximum permissible thickness of the mating part(s). Where the fixed fastener is a stud or press-fit pin the minimum specified length is the maximum length of the projecting portion of the stud or pin.

Where studs or press-fit pins are toleranced for portion on an assembly drawing the specified positional tolerance applies only to the length of the projecting portion of the stud or pin after assembly. Therefore it is unnecessary to specify a projected tolerance zone.

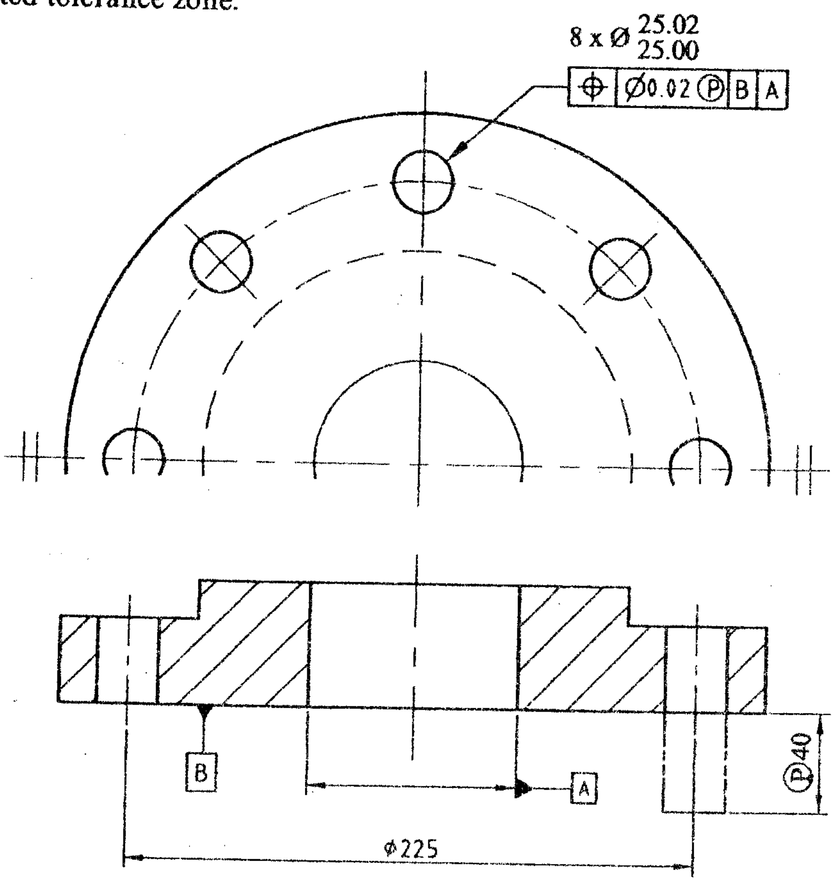


FIGURE 20 - Indication of projected tolerance zone

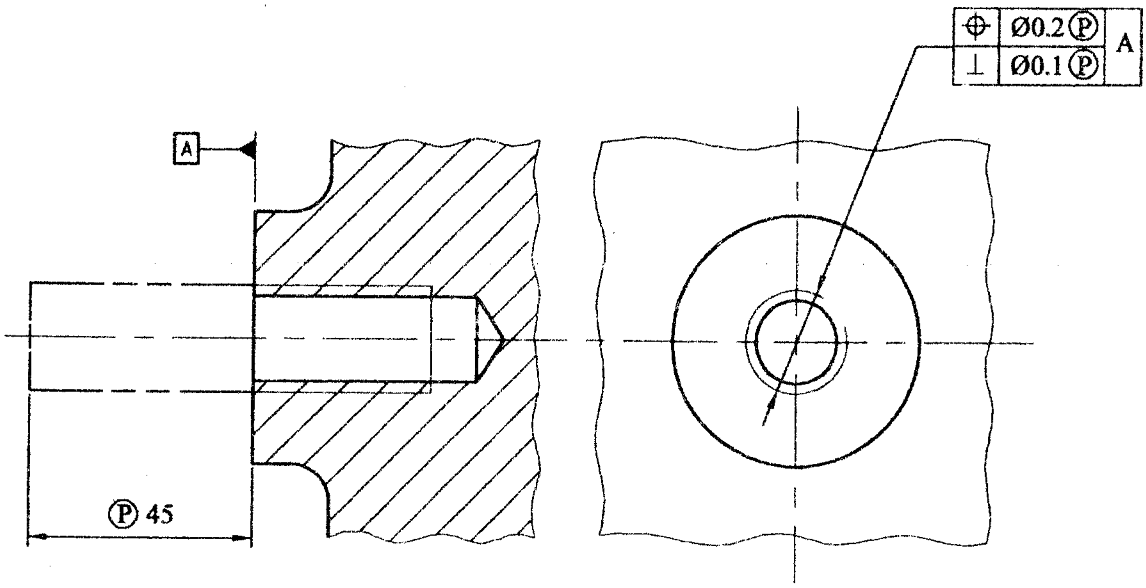


FIGURE 21 - Perpendicularity tolerance applied as a projected tolerance zone

12 DEFINITION, INDICATION AND INTERPRETATION OF TOLERANCE ZONES

12.1 General

There are to possible methods of graphical representation for some tolerance zones (for example, straightness of a line or axis controlled in one direction only);

a) by two parallel planes a distance 't' apart as shown in Figure **2(a)**
b) by two parallel straight lines a distance t apart as shown in Figure **2(b)**

Figure **22(a)** shows three-dimensional representations of a tolerance zone and Figure **22(b)** its projection on a plane. There is no difference in the measuring of two representations, for such a tolerance does not restrict the deviation is in any direction perpendicular to the tolerance zone.

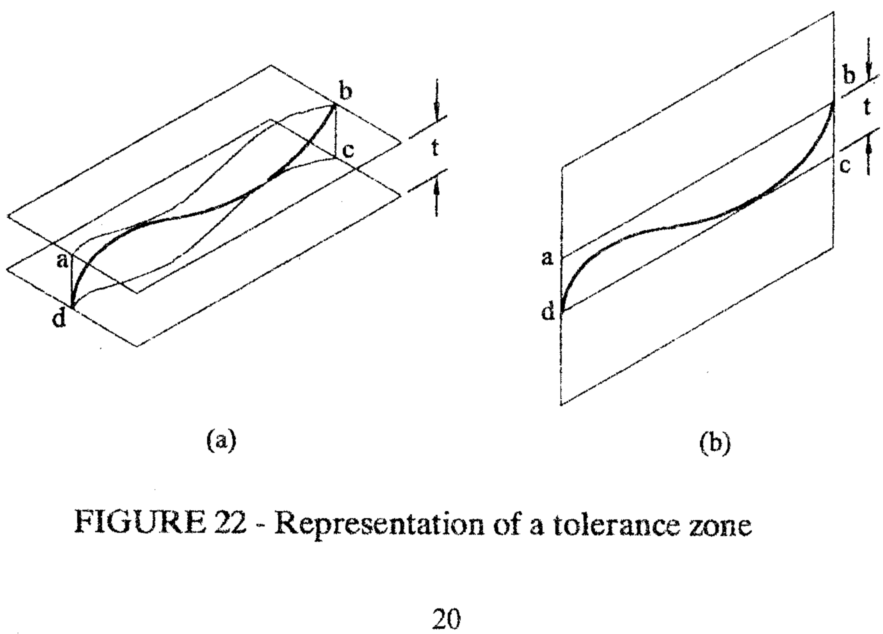
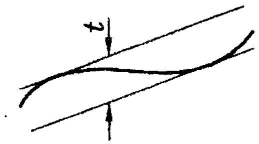
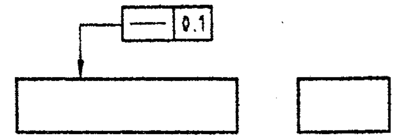
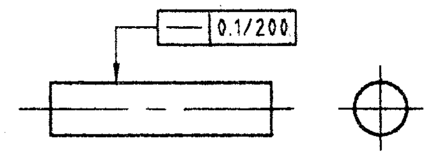
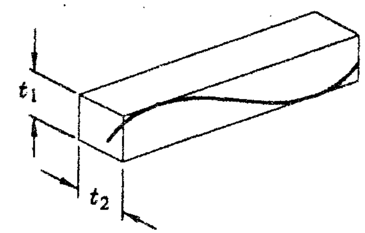
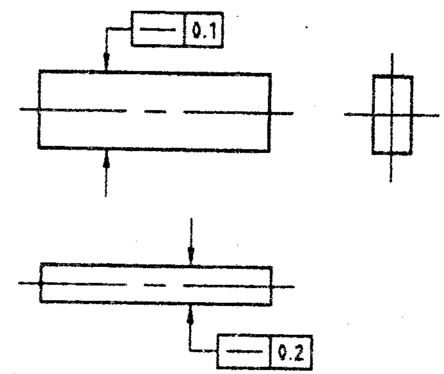
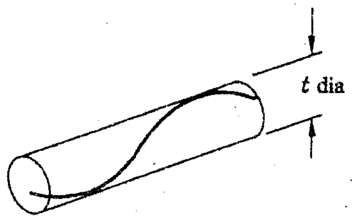
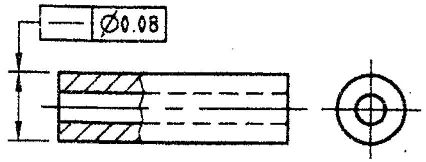
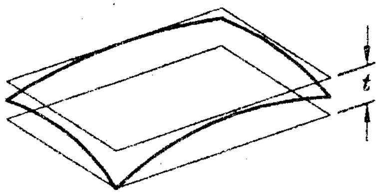
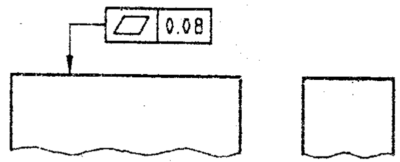


FIGURE 22 - Representation of a tolerance zone

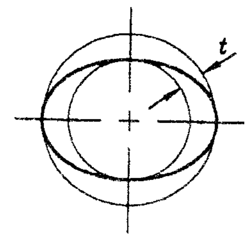
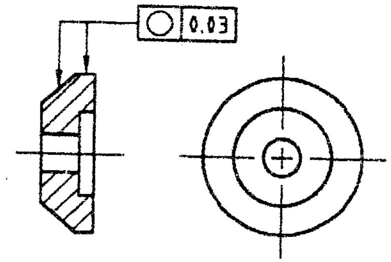
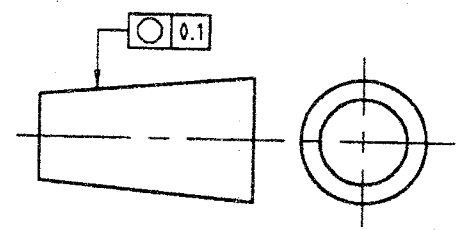
TABLE 2 - Tolerance zones

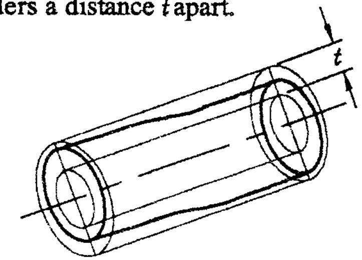
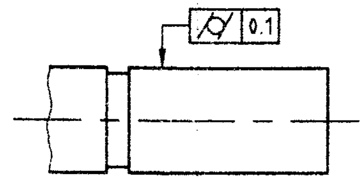
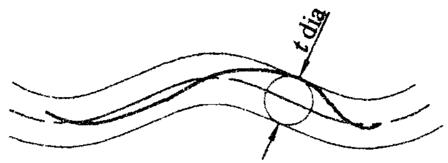
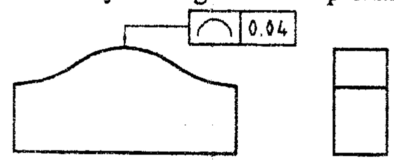
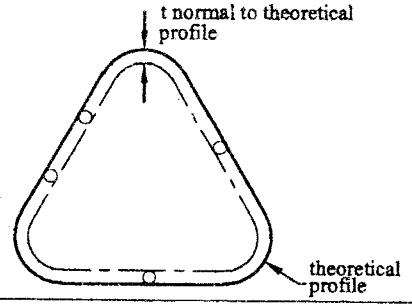
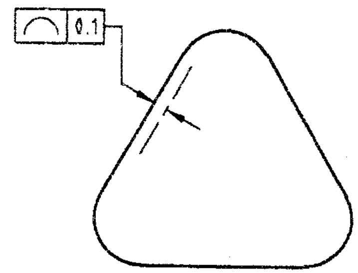
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
1	—	Straightness tolerance	When projected on a plane the tolerance zone is limited by two parallel straight lines a distance t apart. 	 Any line on the upper surface parallel to the plane of projection in which the indication is shown is to be contained between two parallel straight lines 0.1 apart.  Any portion of length 200 of any generator of the cylindrical surface indicated by the arrow is to be contained between two parallel straight lines 0.1 apart in a plane containing the axis

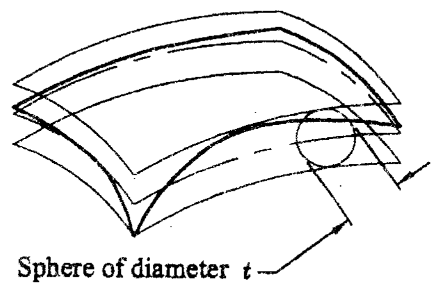
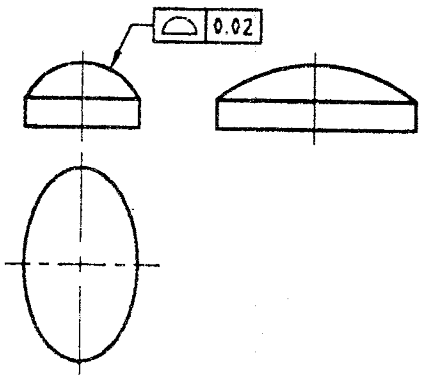
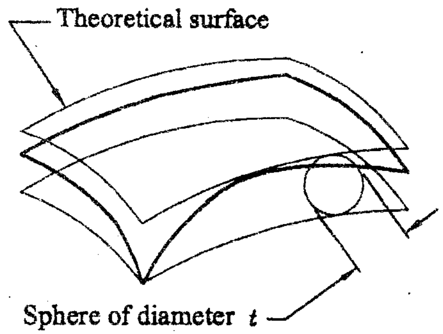
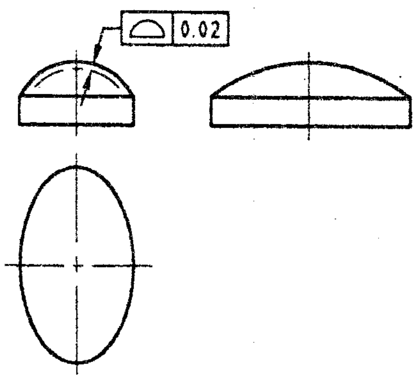
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
			When the tolerance is specified in two directions perpendicular to each other the tolerance zone is limited by a parallelepiped of section $t_1 \times t_2$ 	 The centre line of the bar is to be contained within a parallelepipedic zone of width 0.1 vertically and 0.2 horizontally.

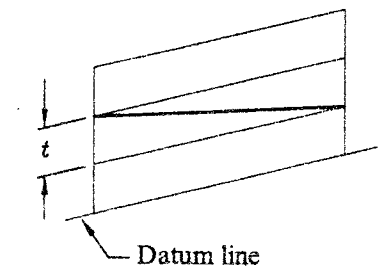
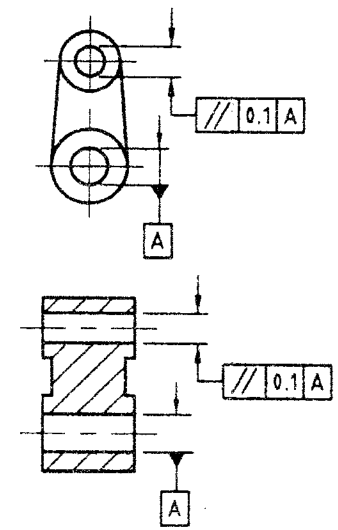
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
			When the tolerance value is preceded by the diameter symbol the tolerance zone is limited by a cylinder of diameter *t* 	 The axis of the cylinder to which the tolerance frame is connected is to be contained within a cylindrical zone of diameter 0.08 *
2	▱	Flatness tolerance	The tolerance zone is limited by two parallel planes a distance *t* apart. 	 The surface is to be contained between two parallel planes 0.08 apart.

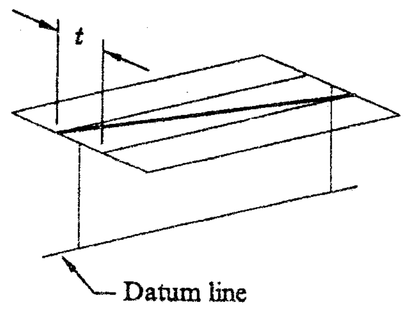
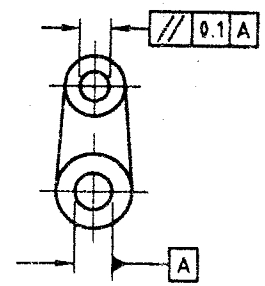
NOTE: *The straightness tolerance of an axis with dependency of size and form is not a limiting value as defined in SLS 409 pt 2.*

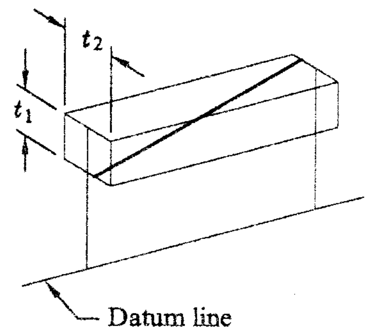
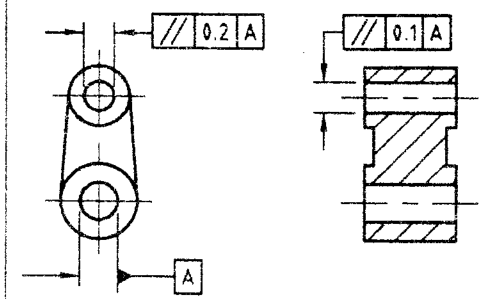
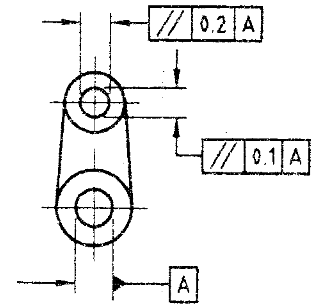
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
3	○	Circularity tolerance (roundness)	The tolerance zone in the considered plane is limited by two concentric circles a distance t apart. 	The circumference of each cross-section of the outer profile is to be contained between two co-planar concentric circles 0.03 apart.   The circumference of each cross-section is to be contained between two co-planar concentric circles 0.1 apart.

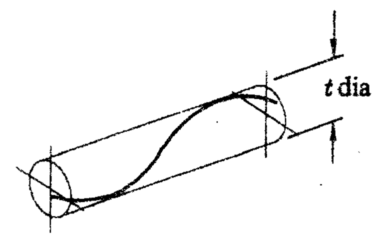
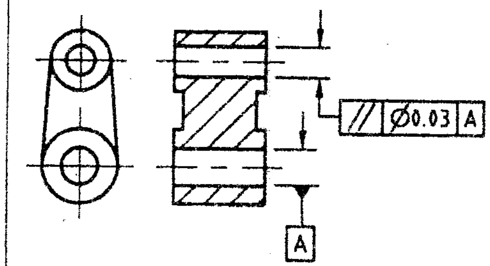
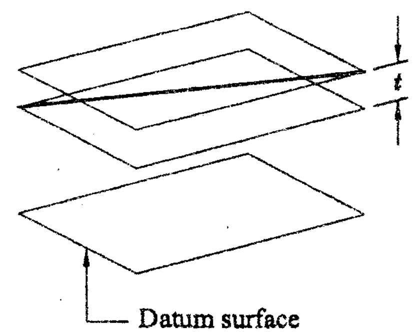
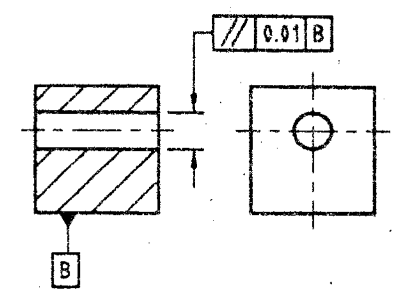
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
4	⌭	Cylindricity tolerance	The tolerance zone is limited by two coaxial cylinders a distance *t* apart. 	 The considered surface is to be contained between two coaxial cylinders 0.1 apart.
5	⌒	Profile tolerance of any line	(a) Bilateral The tolerance zone is limited by two lines enveloping circles of diameter *t* the centres of which are situated on a line having the theoretically exact geometrical form. 	In each section parallel to the plane of projection the considered profile is to be contained between two lines enveloping circles of diameter 0.04, the centres of which are situated on a line of theoretically exact geometrical profile 
			(b) Unilateral The tolerance zone is limited by two lines enveloping circles of diameter *t*, one line being the theoretically exact profile 	In any section parallel to the plane of projection of the drawing, the actual profile is to lie between the theoretical profile and a line which envelops a series of circles 0.1 diameter. 

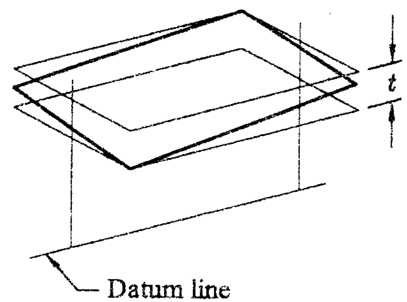
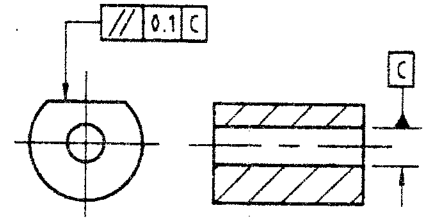
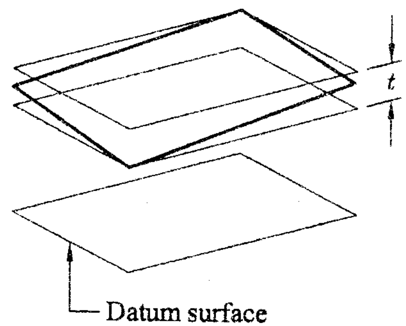
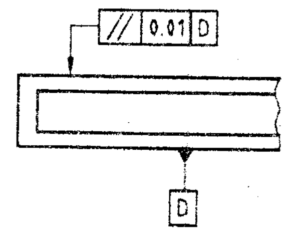
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
6	⌓	Profile tolerance of any surface	(a) Bilateral The tolerance zone is limited by two surfaces enveloping spheres of diameter *t*, the centres of which are situated on a surface having the theoretically exact geometrical form.  	 The considered surface is to be contained between two surfaces enveloping spheres of diameter 0.02, the centres of which are situated on a surface of theoretically exact geometrical form
			(b) Unilateral The tolerance zone is limited by two surfaces enveloping spheres of diameter *t* one being the theoretically exact profile.  	The considered surface is to lie between two surfaces which envelop a series of spheres, 0.02 diameter, one surface being theoretically exact 

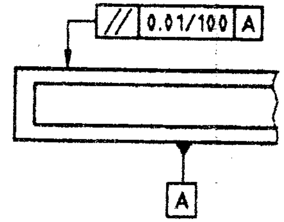
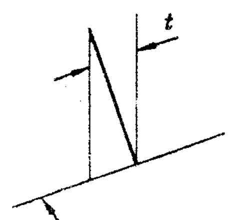
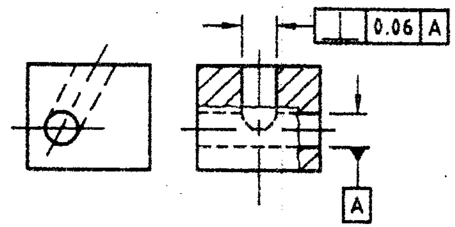
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
7	//	Parallel tolerance		
7.1	//	Parallelism tolerance of a line with tolerance to a datum line	When the tolerance is specified in one direction only the tolerance zone, when projected on a plane , is limited by two parallel straight lines a distance t apart and parallel to the datum line 	 The toleranced axis is to be contained between two straight lines 0.1 apart, which are parallel to the datum axis A and lie in the vertical direction

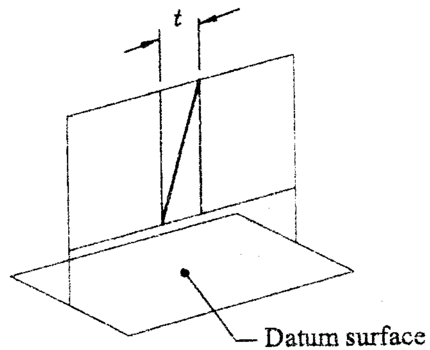
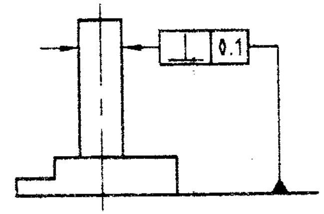
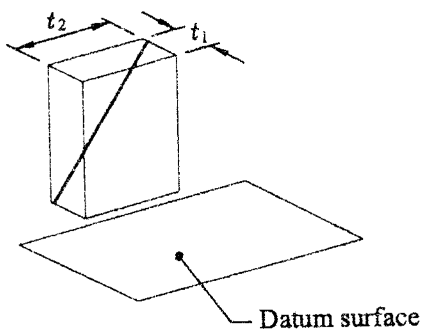
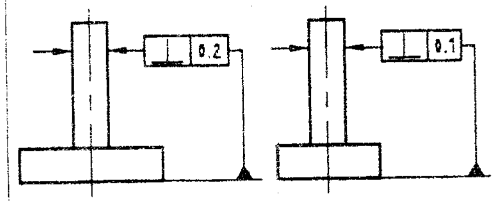
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
				 The toleranced axis is to be contained between two straight lines 0.1 apart, which are parallel to, and symmetrically disposed about, the datum axis A and lie in the horizontal direction

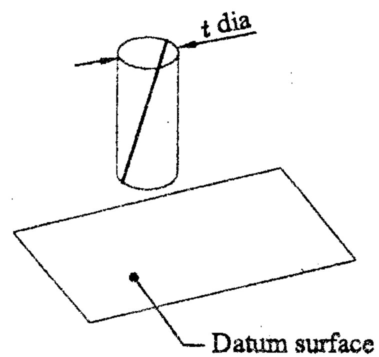
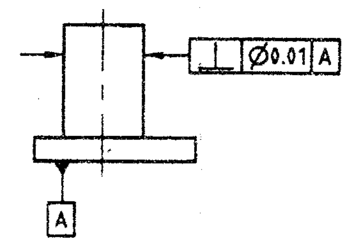
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
7.2	//	Parallelism tolerance of a line with reference to a datum line (concluded)	When the tolerance is specified in two planes perpendicular to each other the tolerance zone is limited by a parallelepiped of section $t_1 \times t_2$ parallel to the datum line. 	 The toleranced axis to be contained within a parallelepiped tolerance zone having a width of 0.2 in the horizontal and 0.1 in the vertical direction and which is parallel to the datum axis A. 

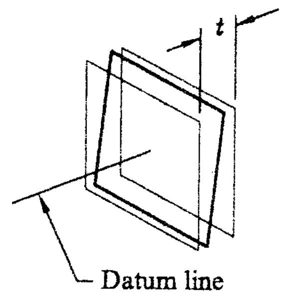
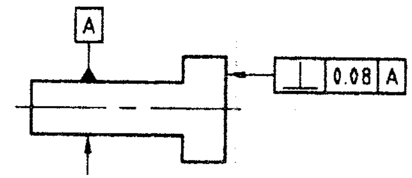
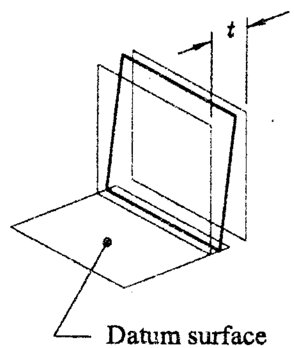
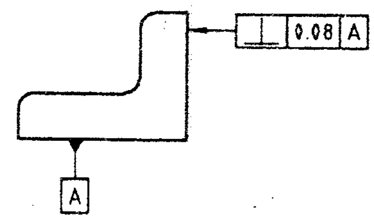
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
			When the tolerance value is preceded by the diameter symbol the tolerance zone is limited by a cylinder of diameter t parallel to the datum line. 	 The tolerance axis is to be contained within a cylindrical zone of diameter 0.03 parallel to the datum axis A (datum line).
7.3	//	Parallelism tolerance of a line with reference to a datum surface	The tolerance zone is limited by two parallel planes a distance t apart and parallel to the datum surface. 	 The axis of the hole is to be contained between two planes 0.01 apart, which are parallel to the datum surface B.

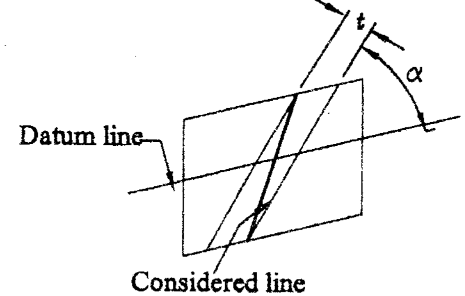
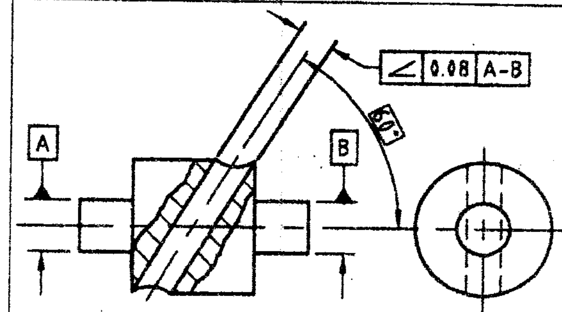
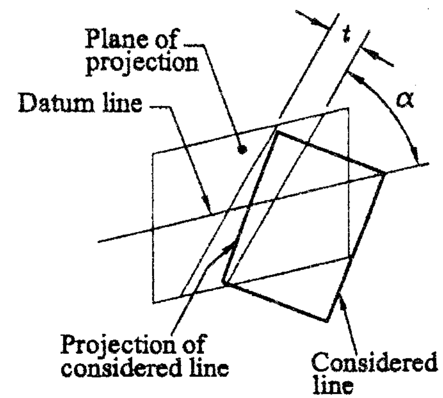
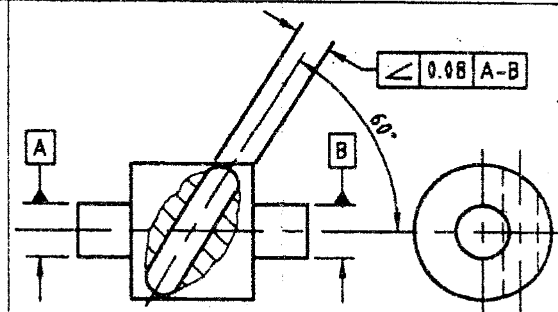
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
7.4	//	Parallelism tolerance of a surface with reference to a datum line	The tolerance zone is limited by two parallel planes a distance *t* apart and parallel to the datum line 	 The toleranced surface is to be contained between two planes 0.1 apart which are parallel to the datum axis C of the hole
7.4	//	Parallelism tolerance of a surface with reference to a datum surface	The tolerance zone is limited by two parallel planes a distance *t* apart and parallel to the datum surface 	 The toleranced surface is to be contained between two parallel planes 0.1 apart, which are parallel to the datum surfaceD.

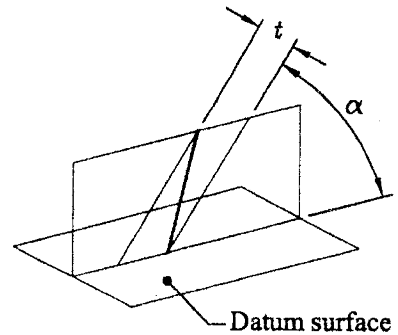
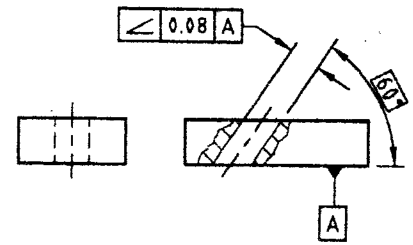
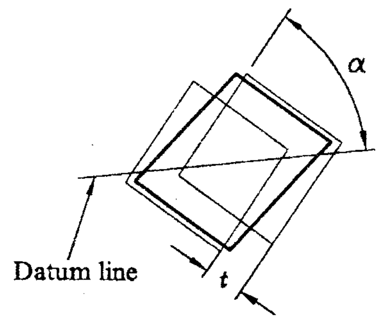
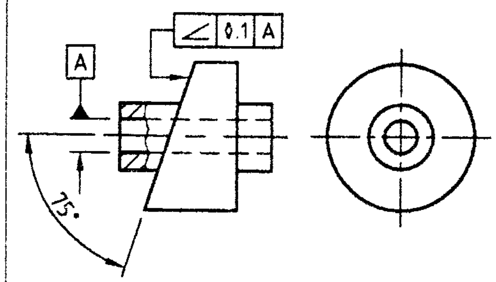
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
				 All the points on the toleranced surface is a length of 100, placed anywhere on this surface, are to be contained between two parallel planes 0.01 apart which are parallel to the datum surface A.
8	$\perp$	Perpendicularity tolerance (squareness)		
8.1	$\perp$	Perpendicularity tolerance of a line with reference to a datum line	The tolerance zone, when projected on a plane, is limited by two parallel straight lines a a distance *t* apart and perpendicular to the datum line. 	 The axis of the inclined hole is to be contained between two parallel planes 0.06 apart which are perpendicular to the axis of the horizontal datum hole A.

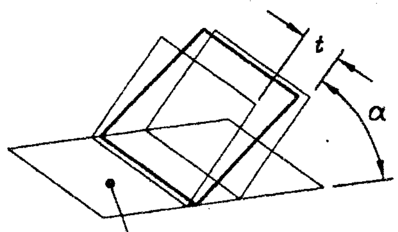
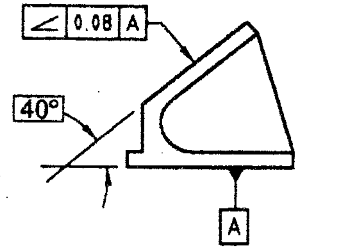
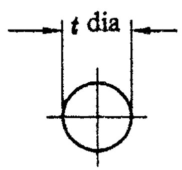
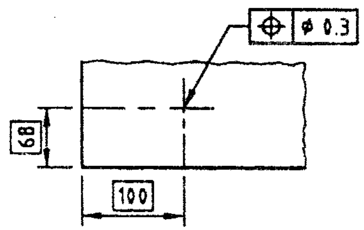
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
8.2	⊥	Perpendicularity tolerance of a line with reference to a datum surface	When the tolerance is specified in one direction only the tolerance zone, when projected on a plane, is limited by two parallel straight lines a distance t apart and perpendicular to the datum surface. 	 The axis of the cylinder is to be contained between two parallel planes 0.1 apart, perpendicular to the datum surface.
			When the tolerance is specified in two directions perpendicular to each other the tolerance zone is limited by a parallelpiped of section t_1 x t_2 and perpendicular to the datum surface. 	 The axis of the cylinder is to be contained within a parallel epipedic zone of 0.1x0.2 which is perpendicular to the datum surface.

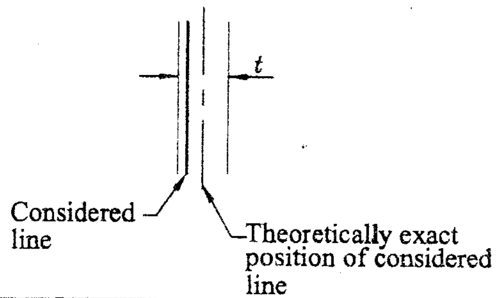
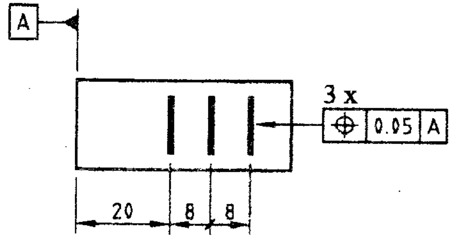
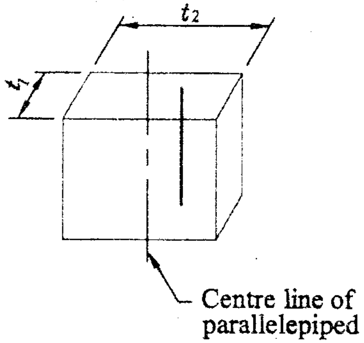
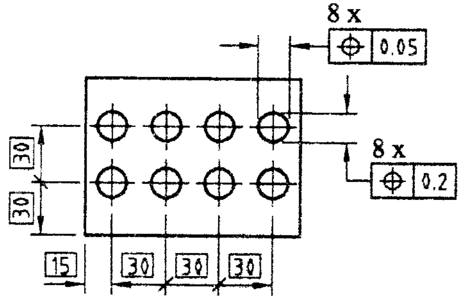
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
	⊥		When the tolerance value preceded by the diameter symbol the tolerance zone is limited by a cylinder of diameter t perpendicular to the datum surface. 	 The axis of the cylinder is to be contained within a cylindrical zone of diameter 0.01 perpendicular to the datum surface A.

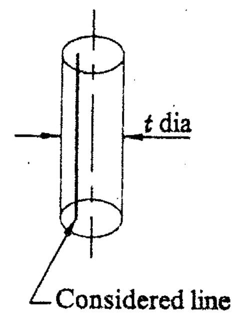
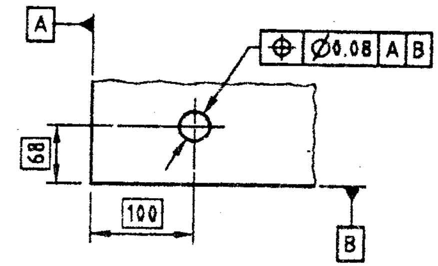
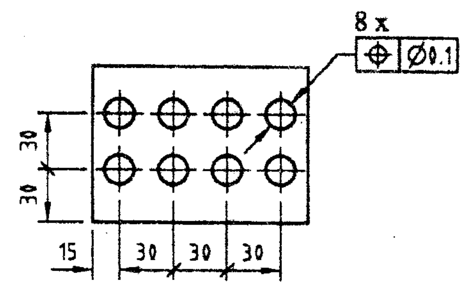
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
8.3	⊥	Perpendicularity tolerance of a surface with referance to a datum line.	The tolerance zone is limited by two parallel planes a distance t apart and perpendicular to the datum line. 	 The tolerance zone is to be contained between two parallel planes 0.08 apart, which are perpendicular to the datum axis A.
	⊥	Perpendicularity tolerance of a surface with referance to a datum surface.	The tolerance zone is limited by two parallel planes a distance t apart and perpendicular to the datum surface. 	 The tolerance zone is to be contained between two parallel planes 0.08 apart, which are perpendicular to the datum surface A.

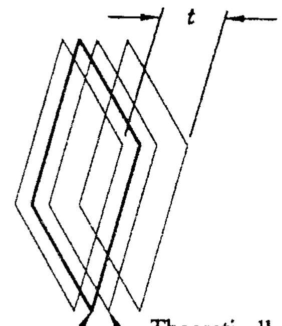
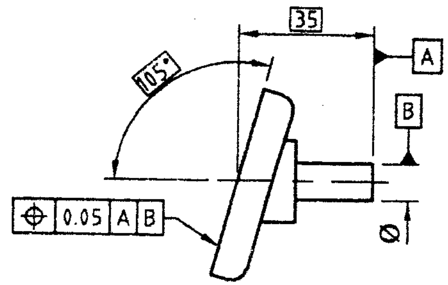
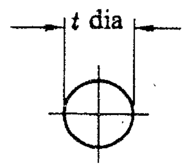
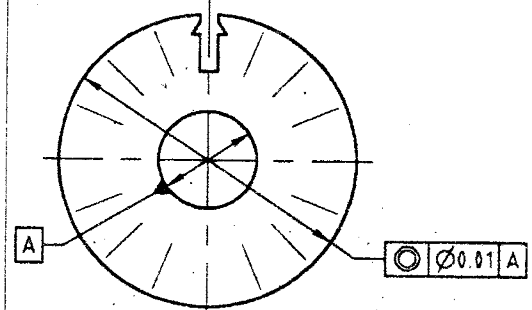
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
9 9.1	∠ ∠	Angularity tolerance Angulatity tolerance of a line with reference to a datum line	(a) Line and datum line in the same plane The tolerance zone, when projected on a lines a distance t apart and inclined at the specified angle to the datum line. 	 The axis of the hole is to be contained between two parallel planes 0.08 apart which are inclined at 60° to the horizontal datum axis A - B.
			(b) Line and datum line in the different planes The tolerance zone is applied to the projection of the considered line on the plane containing the datum line and parallel to the considered line. 	 The axis of the hole, iprojected on a plane containing the datum axis, is to be contained between two parallel straight lines 0.08 apart which are inclined at 60° to the horizontal datum axis A - B.

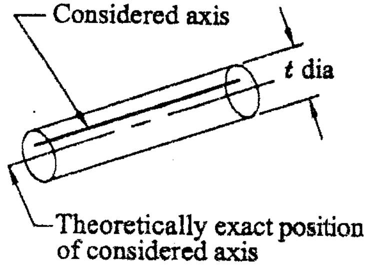
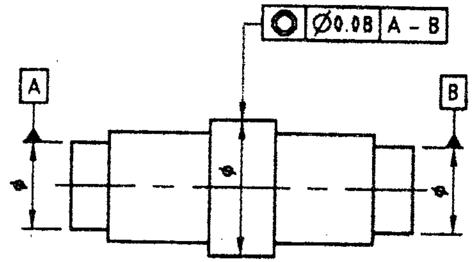
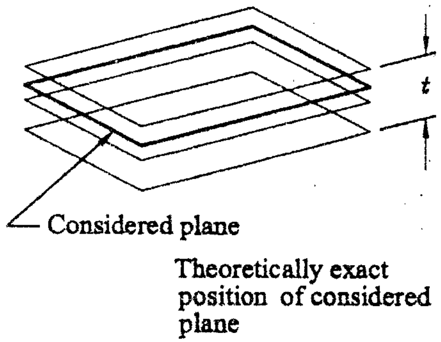
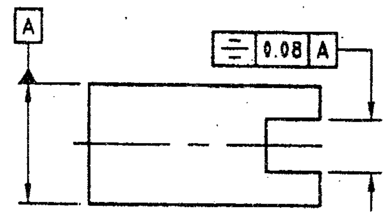
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
9.2	∠	Angularity tolerance of a line with reference to a datum surface.	The tolerance zone, when projected on a plane, is limited by two parallel straight lines a distance t apart and inclined at the specified angle to the datum surface. 	 The axis of the hole is to be contained between two parallel planes 0.08 apart which are inclined at 60° to datum surface A.
9.3	∠	Angularity tolerance of a surface with reference to a datum line.	The tolerance zone is limited by two parallel planes a distance t apart and inclined at the specified angle to the datum line. 	 The inclined surface is to be contained between two parallel planes 0.1 apart which are inclined at 75° to datum axis A.

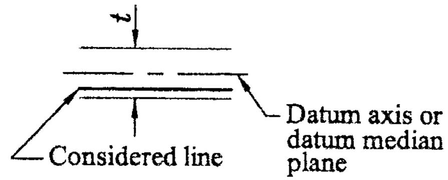
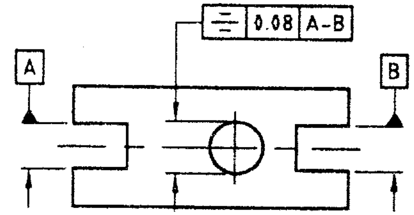
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
9.4	∠	Angularity tolerance of a surface with reference to a datum surface.	The tolerance zone is limited by a circle of diameter t, the centre of which is in the theoretically exact position of the considered position. 	 The inclined surface is to be contained between two parallel planes 0.08 apart which are inclined at 40° to the datum surface A.
10	⌖	Positional tolerance		
10.1	⌖	Positional tolerance of a point	The tolerance zone is limited by a circle of diameter t, the centre of which is in the theoretically exact position of the considered position. 	 The actual point of intersection is to be contained within a circular zone of 0.3 diameter, the centre of which coincides with the theoretically exact position of the considered point of intersection.

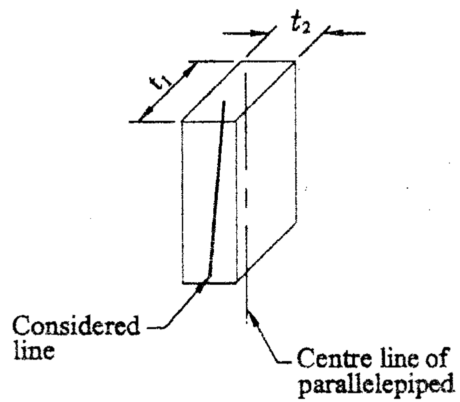
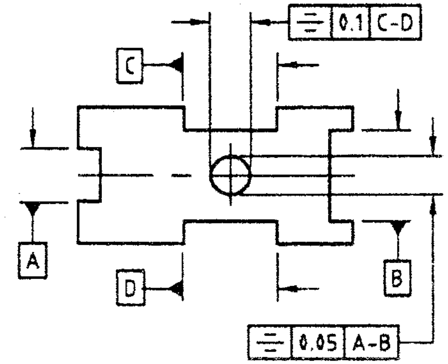
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
10.2	⌖	Positional tolerance of a line	When the tolerance is specified on one direction only the tolerance zone is limited by two parallel straight lines (at a distance t apart) which are disposed symmetrically about the theoretically exact position of the considered line. 	 Each of the lines is to be contained between two parallel straight lines 0.05 apart which are symmetrically disposed about the theoretically exact position of the considered within a cylindrical zone of diameter 0.01 line with reference to datum A.
			When the tolerance is specified in two directions perpendicular to each other the tolerance zone is limited by a parallelepiped of section t_1 x t_2 the centre line of which is in the theoretically exact position of the considered line. 	 Each of the axis of the eight holes is to be contained within a parallelepipedic zone of width 0.05 in the horizontal and 0.2 in the vertical direction the centre line of which is in the theoretically exact pposition of the considered hole axis.

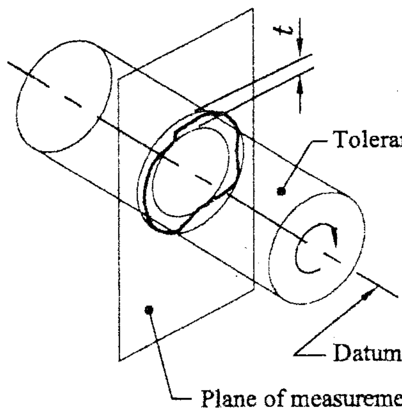
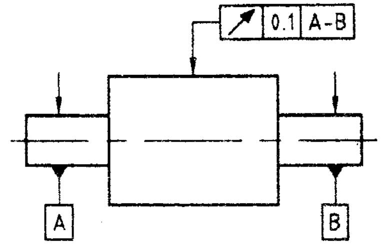
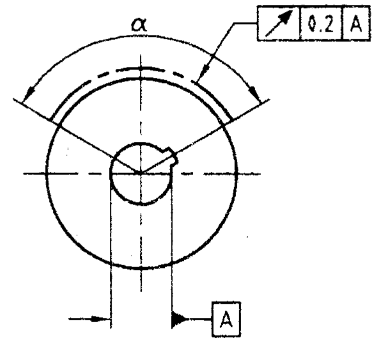
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
10.2	⌖	Positional tolerance of a line	When the tolerance value is preceded by the diameter symbol the tolerance zone is limited by a cylinder of diameter t the axis of which is in the theoretically exact position of the considered line. 	 The axis of the hole is to be contained within a cylindrical zone of diameter 0.08 the axis of which is in the theoretically exact position of the considered line, with reference to the datum surfaces A and B.  Each of the axes of the eight holes is to be contained within a cylindrical zone of diameter 0.1 the axis of which is in the theoretically exact position of the considered hole axis.

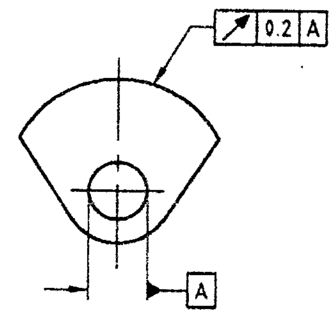
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
10.3	⌖	Positional tolerance of a flat surface or a median plane	The tolerance zone is limited by two parallel planes a distance t apart and disposed symmetrically about the theoretically exact position of the considered surface, or plane 	 The inclined surface is to be contained between two parallel planes which are 0.05 apart and which are symmetrically disposed about the theoretically exact position of the considered surface with reference to datum A and the axis of the datum cylinder B.
11	◎	Concentricity and coaxiality tolerance		
11.1	◎	Concentricity tolerance of a point	The tolerance zone is limited by a circle of diameter t the centre of which coincides with the datum point. 	 The inclined surface is to be contained between two parallel planes which are 0.05 apart and which are symmetrically disposed about the theoretically exact position of the considered surface with reference to datum A

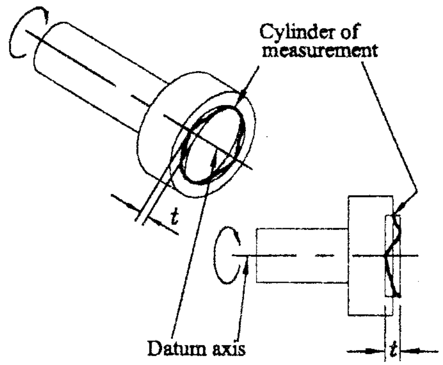
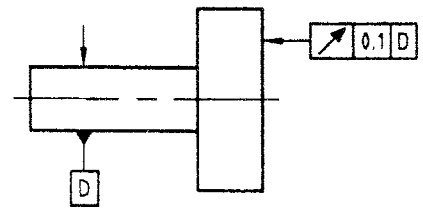
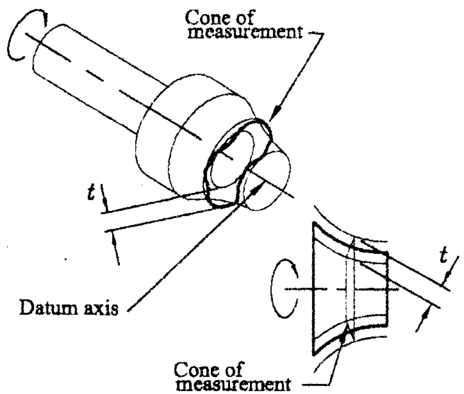
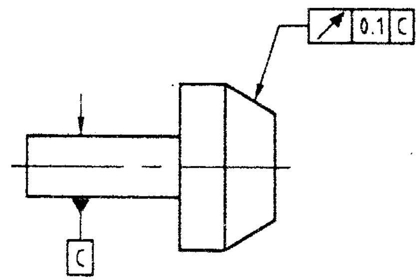
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
11.2	◎	Coaxiality tolerance of an axis	When the tolerance value is preceded by the diameter symbol the tolerance zone is limited by a cylinder of diameter t, the axis of which coincides with the datum axis. 	 The axis of the cylinder is to be contained within a cylindrical zone of diameter 0.08 coaxil with the datum axis A-B.
12 12.1	⌯ ⌯	Symmetry tolerance Symmetry tolerance of a median plane	The tolerance zone is limited by two parallel planes a distance t apart and disposed symmetrically about the datum axis or datum median plane. 	 The median plane of the slot is to be contained between two parallel planes which are 0.08 apart and symmetrically disposed about the median plane of the datum feature A.

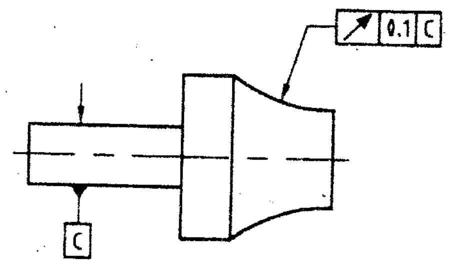
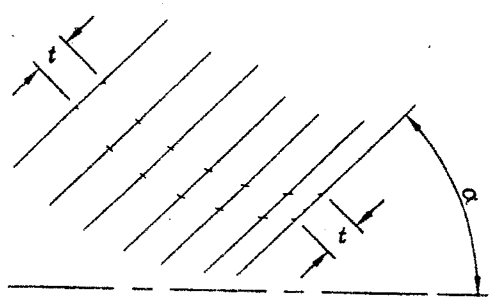
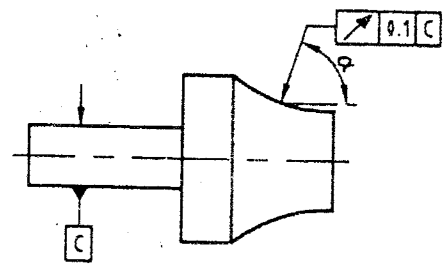
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
12.2	⌯	Symmetry tolerance of a line or an axis	When the tolerance is specified in one direction only the tolerance zone, when projected on a plane, is limited by two are disposed symmetrically about the datum axis or datum median plane. of diameter t, the centre of which is in the 	 The axis of the hole is to be contained between two parallel planes which are 0.08 apart and symmetrically disposed about the actual common median plane of the datum slots A and B.

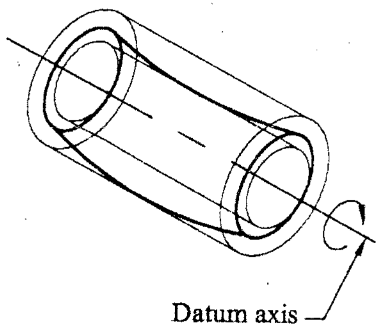
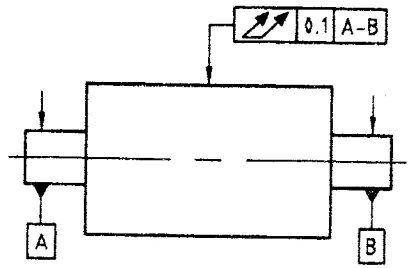
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
	⌯		When the tolerance is specified in two directions perpendicular to each other the tolerance zone is limited by a parallelepiped of section t_1 x t_2, the centre line of which coincides twith the datum axis. 	 The axis of the hole is to be contained within a parallelepipedic zone of width 0.1 in the horizontal and 0.05 in the vertical direction, the centre line of which coincides with the datum line formed by the intersection of the common median planes A-B and C-D.

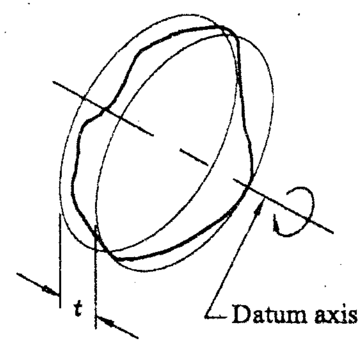
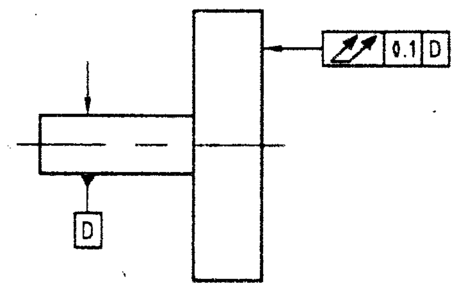
Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
13	↗	Circular run-out tolerance		
13.1	↗	Circular run-out tolerance	Within any plane of measurement perpendicular to the axis the tolerance zone is limited by two concentric circles a distance t apart, the centre of which coincides with the datum axis.  NOTE : *Run–out is usually applied to complete revolutions about the axis unless limited to apply to a part of a revolution.*	 The radial run-out is to be not greater than 0.1 in any plane of measurement during one revolution about the datum axis A-B. 

Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
				 The radial run-out is to be not greater than 0.2 in any plane of measurement when measuring the toleranced part of a revolution about the axis of datum hole A.

Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
13.2		Circular run-out tolerance: axial	At any radial position the tolerance zone is limited by two circles a distance *t* apart lying in a cylinder of measurement, the axis of which coincides with the datum axis. 	 The axial run-out is to be not greater than 0.1 at any position of measurement during one revolution about the datum axis D.
13.3		Circular run-out tolerance in any direction	 Within any cone of measurement the tolerance zone is limited by two circles a distance *t* apart. The axis of the cone of measurement coincides with the datum axis. Unless otherwise specified the direction of measurement is perpendicular to the surface.	 The run-out in the direction indicated by the arrow is to be not greater than 0.1 in any cone of measurement during one revolution about the datum axis C.

Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
				 The run-out in the direction perpendicular to the tangent of the curved surface is to be not greater than 0.1 in any cone of measurement during one revolution about the datum axis C.
13.4	↗	Circular run-out tolerance in a specified direction	Within any cone of measurement of the specified angle the tolerance zone is limited by two circles a distance t apart. The axis of the cone of measurement coincides with the datum axis. 	 The run-out in the specified direction is to be not greater than 0.1 in any cone of measurement during one revolution about the datum axis C.

Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
14		Total run-out tolerance		
14.1		Total radial run-out tolerance	The tolerance zone is limited by two coaxial cylinders a distance t apart, the axis of which coincide with the datum axis. 	 The total run-out is to be not greater than 0.1 at any point on the specified surface whilst revolving about the datum axis A-B, and with relative axial movement between measuring instrument and the workpiece. With relative movement the measuring instrument or the workpiece is to be guided along a line having the theoretically exact form of the contour and being in its correct position relative to the datum axis.

Item no (1)	Symbol (2)	Tolerance characteristic (3)	Definition of tolerance zone (4)	Indication and interpretation (5)
14.2		Total axial run-out tolerance	The tolerance zone is limited by two parallel planes a distance *t* apart and perpendicular to the datum axis. 	 The total run-out is to be not greater than 0.1 at any point on the specified surface whilst revolving about the datum axis D and with relative radial movement between the measuring instrument and the workpiece. With relative movement the measuring instrument or the workpiece is to be guided along a line having the theoretically exact form of the contour and being in its correct position relative to the datum axis.

13 ENVELOPE REQUIREMENT

13.1 General

When tolerancing with independency of size and form is used (see Clause **11** of **BS 308 - Part 2**), the envelope requirement may be locally applied to a single feature of size (either a cylindrical surface or a feature established by two plane parallel surfaces). The requirement means that the boundary of perfect form at maximum material size of the feature of-size is not to be violated.

The envelope requirement is indicated by the symbol Ⓔ placed after the size dimension as shown in Figure **23(a)**.

13.2 Envelope requirement applied to a cylindrical feature

13.2.1 *Drawing indication.*

The drawing indication is shown in Figure **23(a)**.

13.2.2 *Functional requirements*

The drawing in Figure **23(a)** indicates the following functional requirements.

a) the surface of the cylindrical feature is not to extend beyond the envelope of perfect form at the maximum material size of 150 diameter.

b) no actual local size is to be less than 149.96 diameter.

13.2.3 *Interpretation*

The actual part is to meet the following requirements.

a) each actual local diameter of the cylindrical feature is to remain within the size tolerance of 0.04 and, therefore, may vary between 150 diameter and 149.96 diameter (see Figure **23(b)**).

b) the entire cylindrical feature is to remain within the boundary of the enveloping cylinder of perfect form of 150 diameter (see Figure **23(c)** and **(d)**).

It follows that the feature is to be exactly cylindrical when all actual local diameters are at the maximum material size of 150 diameter (see Figure **23 (e)**).

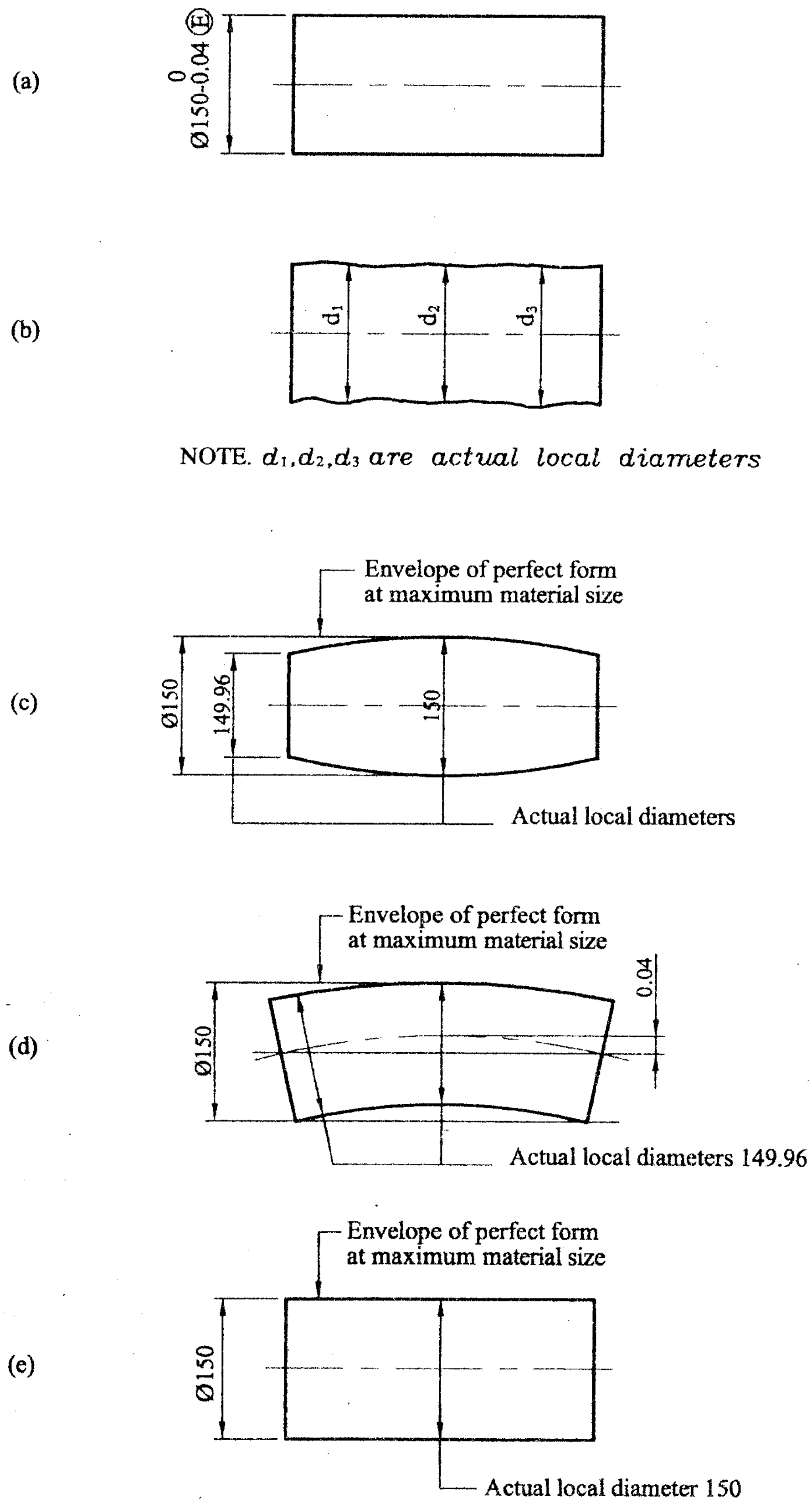


FIGURE 23 - Envelope requirement applied to a cylindrical feature

14 DATUMS AND DATUM SYSTEMS

14.1 General

Datum and datum systems are used to establish the relationship of geometrically toleranced feature. It is usually impracticable to measure form theoretical datum planes or axes. The planes or axes are therefore assumed to exist, not in the part itself, but in precisely made manufacturing fixtures or inspection equipment, the surface of which are of such a high quality that they are deemed to simulate perfect planes or to define axes.

15 INDICATION OF DATUMS AND DATUM SYSTEMS

15.1 Indication of datums and datum features (See 7)

15.2 The indication of datums and datum systems in a tolerance frame.

15.2.1 ***Datum established by a single feature.***

Where the datum is established by a single feature, it should be indicated by a letter in the their compartment of the tolerance frame (see Figure **24(a)**).

15.2.2 ***A common datum established by two features.***

Where a common datum is established by two feature, it should be indicated in the third compartment of the tolerance frame by two letters separated by a hyphen (see Figure **24(b)**).

15.2.3 ***Datum system established by two or more datum features***

15.2.3.1 Where the order of priority of the datum is significant, the letters identifying the datum should be placed in separate compartments as shown in Figure **24(c),** where the sequence from left to right indicates the order of priority.

15.2.3.2 The choice of sequence of the datums can have considerable influence on the result obtained (see Figure **25**), but where the order of priority of the datums is not significant, the letters identifying the datums should be placed together in the third compartment of the tolerance frame (see Figure **24(d)**).

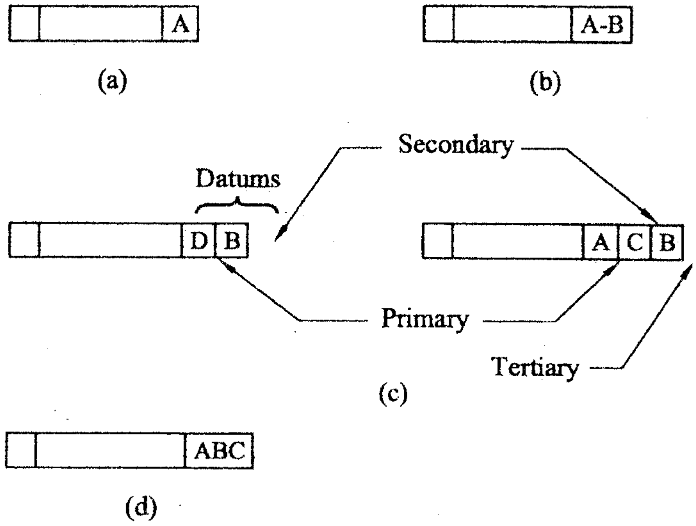
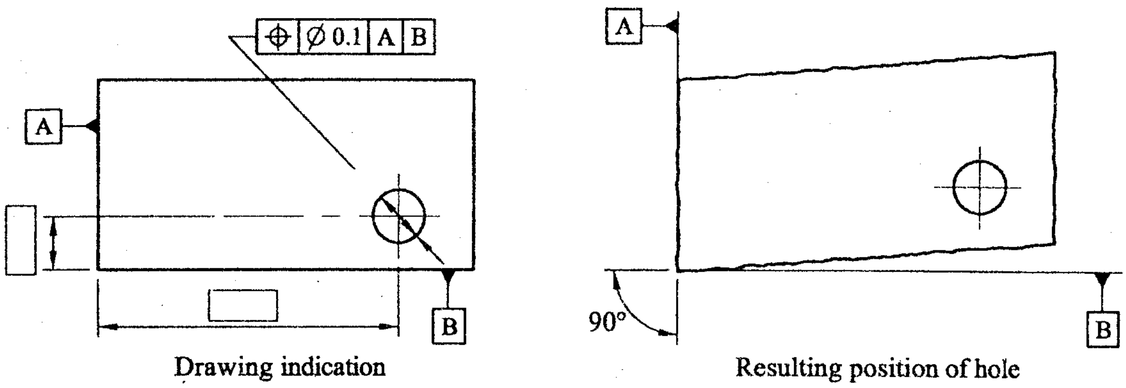
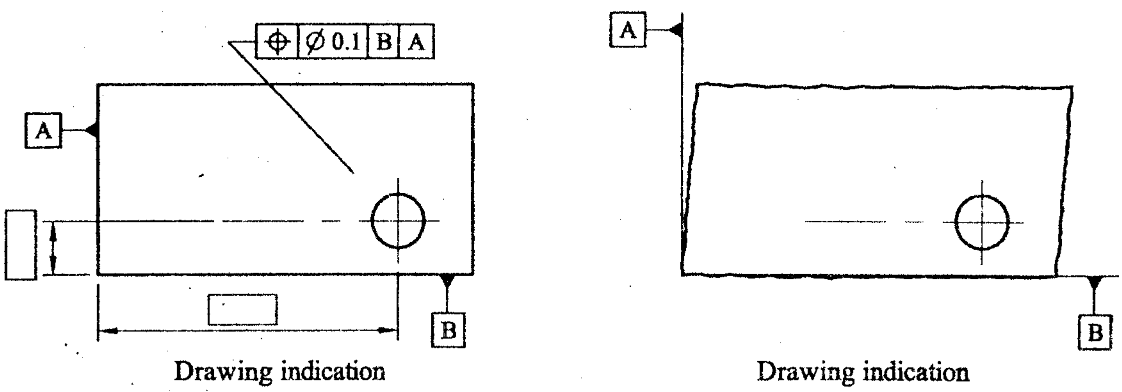


FIGURE 24 - Indication of datums and datum systems in tolerance frames



NOTE. *A is primary datum*
B is secondary datum

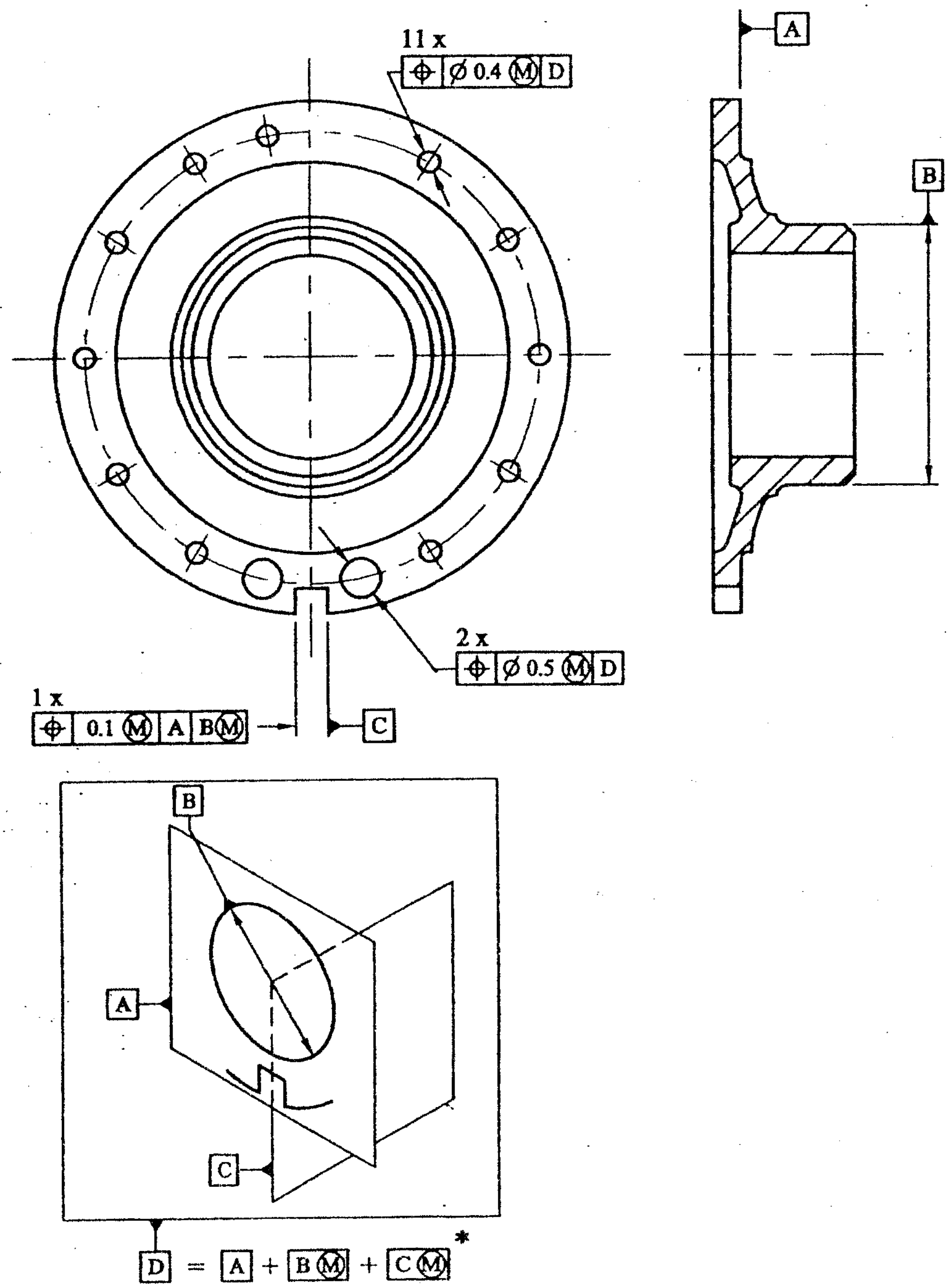


NOTE. *B is primary datum*
A is secondary datum

FIGURE 25 - Interpretation of datum sequence

15.2.3.3 Where the datum system is complex it may be identified by a single letter (see Figure **26**).

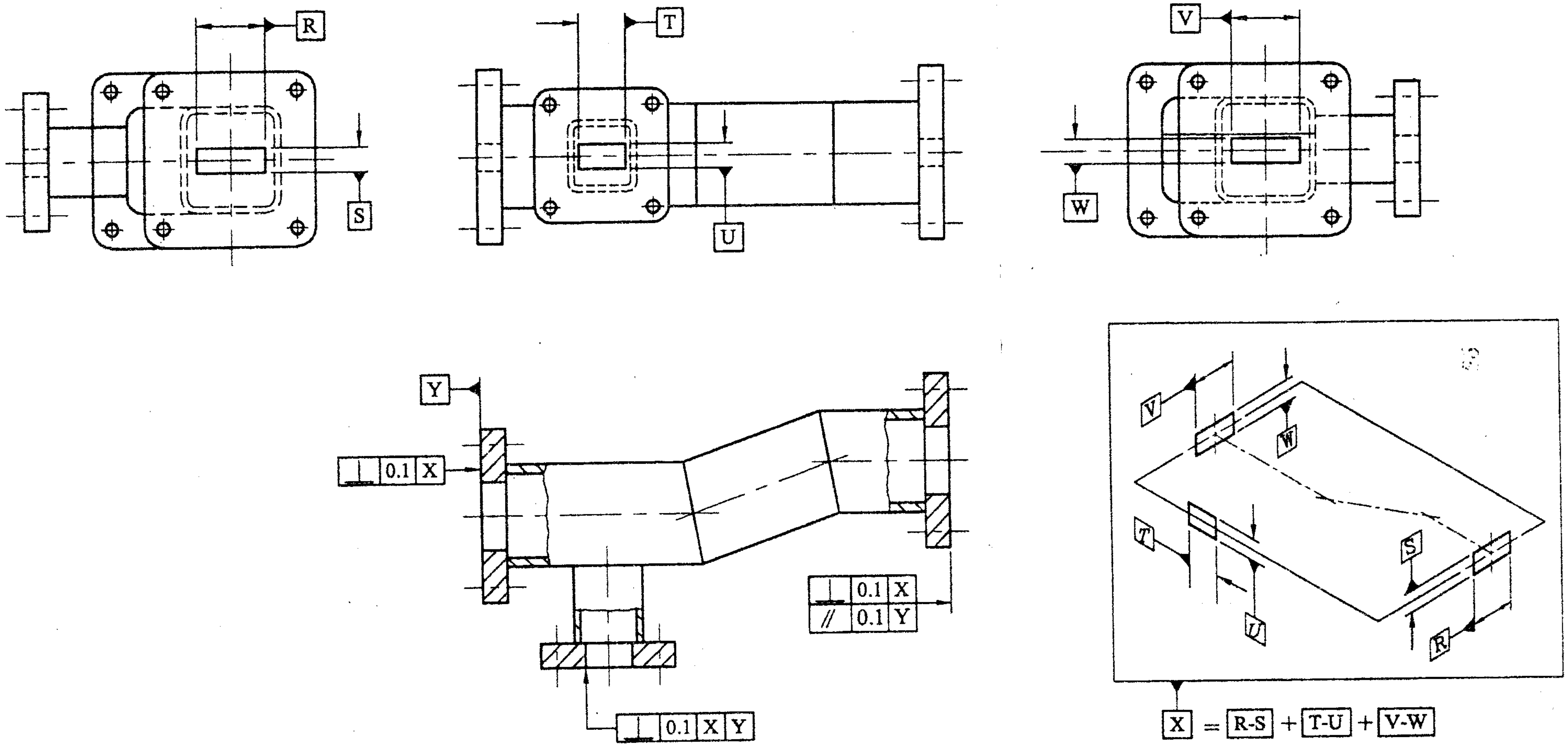
The drawing should include on additional explanatory drawing showing the datums, which make up the multiple datum system. The single letter in the tolerance frame is related to the datums shown by a datum equation given in the explanatory drawing. The sequence of datums from left to right in the datum equation indicates the order of priority.



* Note this equation has the same meaning as | | | A | BⓂ | CⓂ |

(a) Housing

FIGURE 26 - Examples of a datum system identified by a single letter (continued)



(b) Rectangular tube assembly

FIGURE 26 - Examples of a datum system identified by a single letter (concluded)

16 THE ESTABLISHMENT OF DATUMS FROM DATUM FEATURES

16.1 General

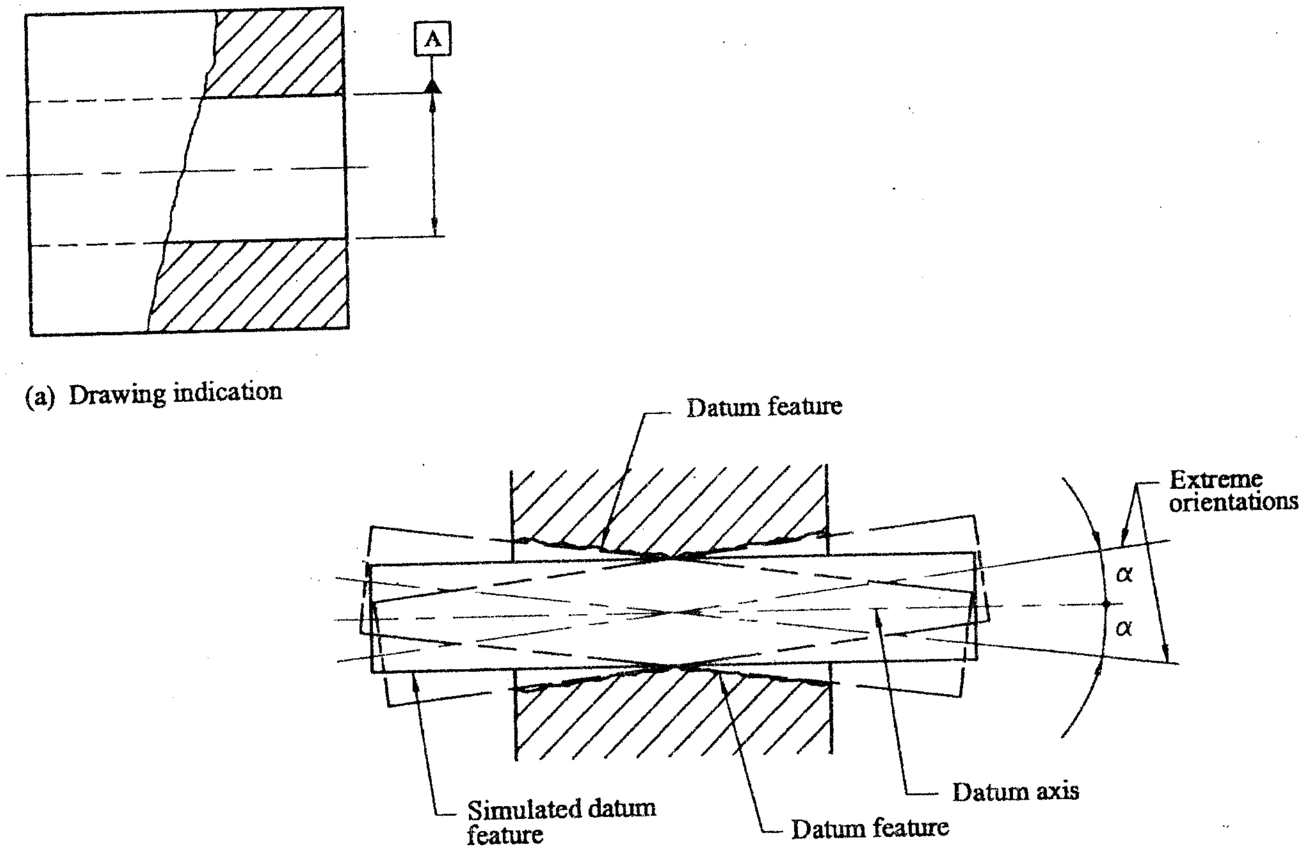
When establishing datums, the following methods may be used to allow for manufacturing imperfections of the datum feature(s).

16.2 Datum being a straight line or a plane

The datum feature should be arranged in such a way that the maximum distance between it and the simulated datum feature have the least possible value.

16.3 Datum being the axis of a cylinder

The datum should be the axis of the largest inscribed cylinder (simulated datum feature) of a hole (see Figure 27), or the smallest circumscribed cylinder of a shaft, so orientated that any possible angular movement of the cylinder in any plane is equalized.



(a) Drawing indication

(b) Interpretation

FIGURE 27 - Datum being axis of a cylinder

16.4 Datum being a common axis

In Figure **28** the datum is the common axis of the two smallest circumscribed coaxial cylinders.

NOTE: *Depending on circumstances the position and length of the simulated datum may need to be indicated as less than the overall length of the datum feature.*

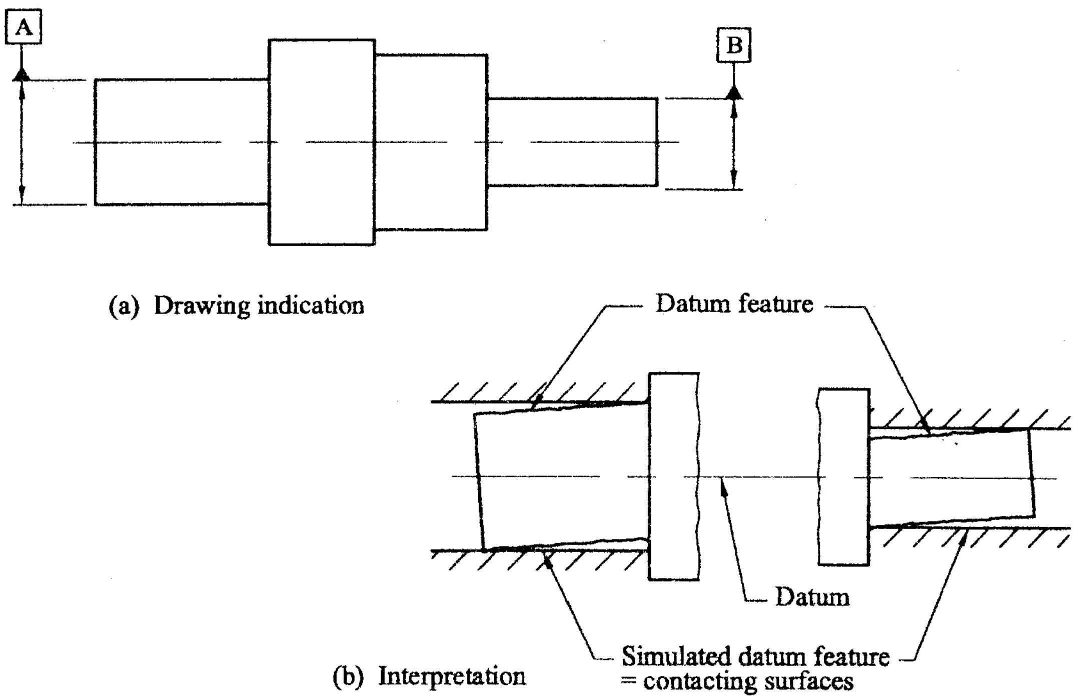
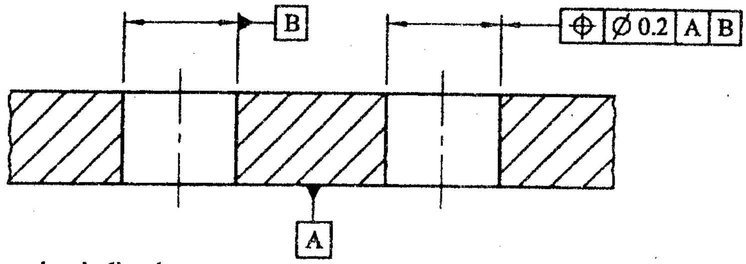


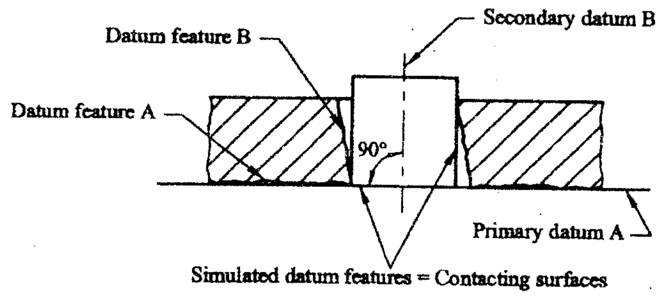
FIGURE 28 - Common axis datum

16.5 Datums being a plane and the axis of a perpendicular cylinder

In Figure **29** primary datum A is the plane represented by the contacting flat surface. Secondary datum B is the axis of the largest inscribed cylinder, perpendicular to datum A.



(a) Drawing indication



(b) Interpretation of datum hole

FIGURE 29 - Datums being a plane and the axis of a perpendicular cylinder

17 APPLICATION OF DATUM

Table 3 shows examples of :

a) the indication of datums
b) the datum feature; and
c) how datums are established by means of simulated datum feature

TABLE 3 - Examples of application of datum (continued)

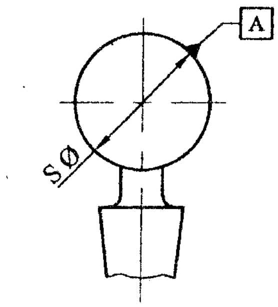
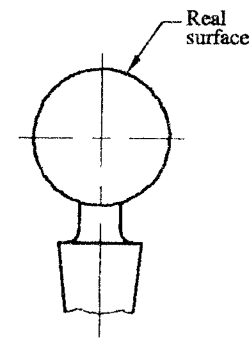
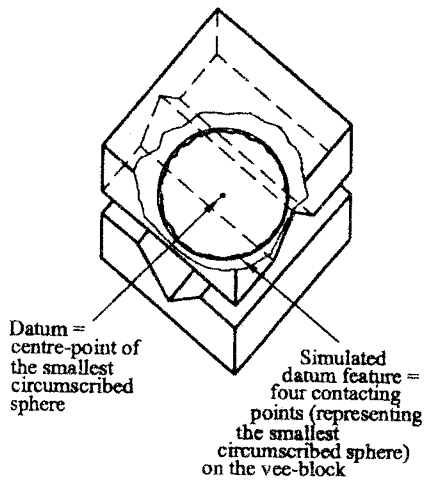
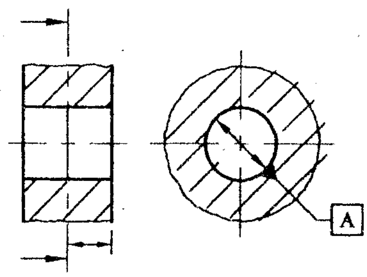
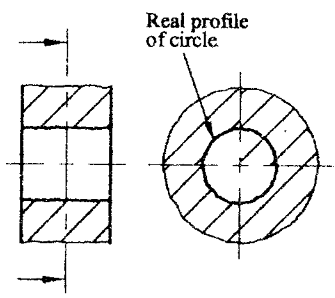
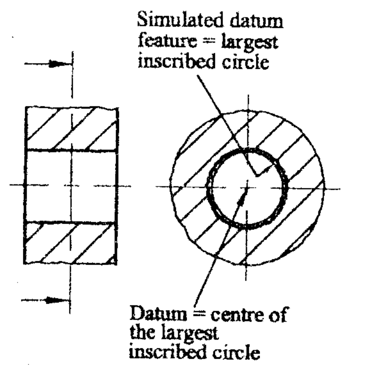
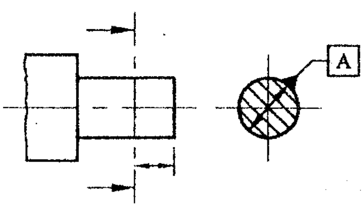
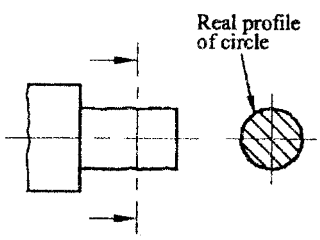
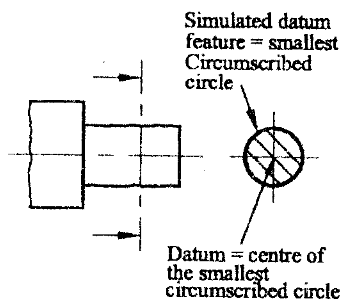
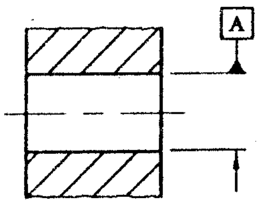
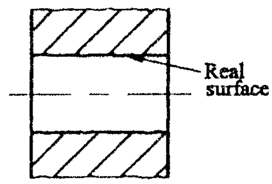
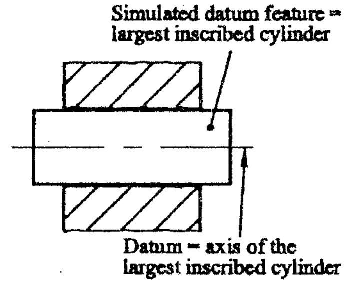
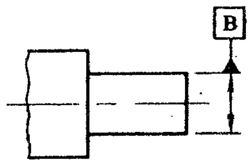
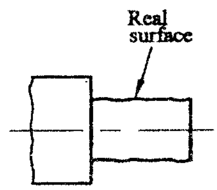
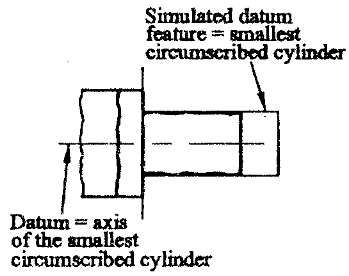
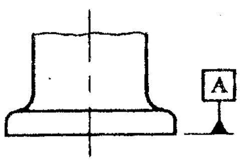
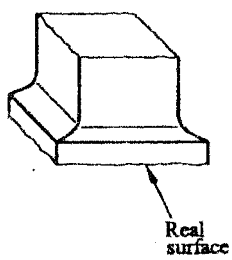
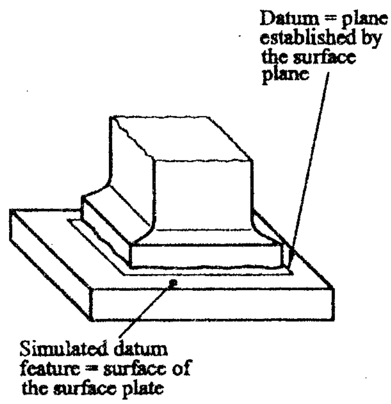
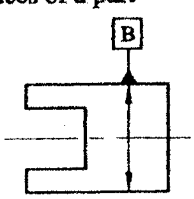
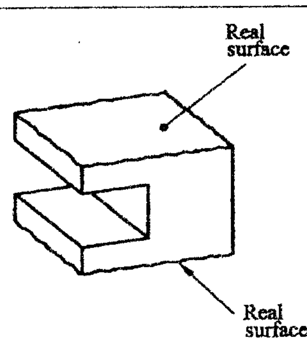
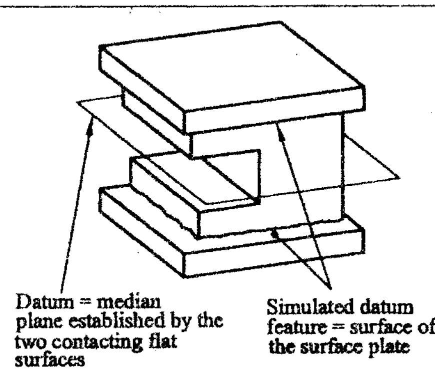
Drawing indication of datum (1)	Datum feature (2)	Establishment of datum (3)
(a) Centre-point of a sphere		
Centre-point of a sphere 		
Centre-point of a circle (Hole) 		
Centre-point of a circle (Shaft) 		

TABLE 3 - Examples of application of datum (concluded)

Drawing indication of datum (1)	Datum feature (2)	Establishment of datum (3)
(b) Datum : line		
Axis of a hole 		
		
(c) Datum : plane		
Surface of a part 		
(d) Datum : median plane		
Median plane of the two surfaces of a part 		

18 DATUM TARGETS

In the case of a surface, the datum feature may vary significantly from its ideal form. Thus, specification of a total surface as a datum feature may introduce variance or lack or repeatability in measurements taken from it (see Figure **30** and **31**).

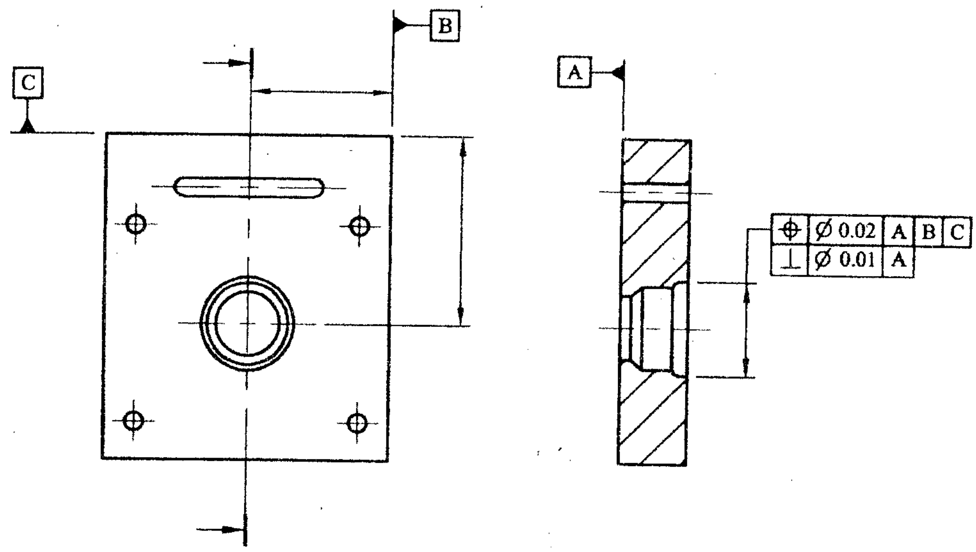


FIGURE 30 - Demonstration of imperfect datum surfaces (drawing indication)

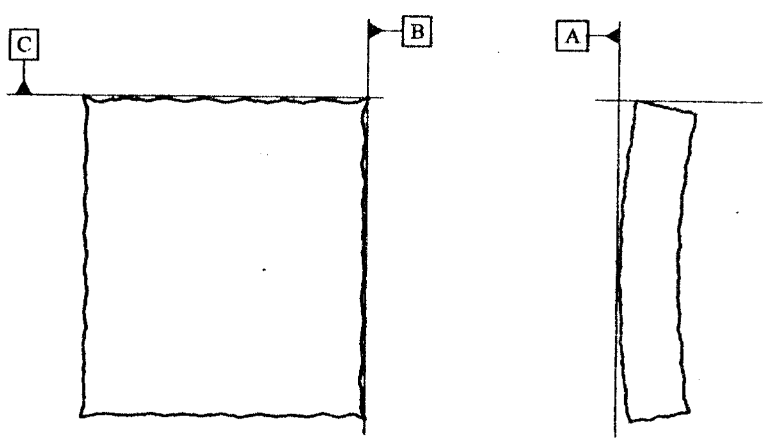


FIGURE 31 - Possible situation exaggerated

It may therefore be necessary to introduce datum targets.

Before specifying the datum targets, it is necessary to consider whether the functioning of the part may be endangered by specifying the datum to consist only of datum targets instead of the whole surface. In this respect the influence of the deviations from the ideal geometrical form and positions, which may occur, shall be considered.

18.1 Symbol for datum

To indicate the datum targets on a drawing, the following symbols shall be used.

18.1.1 *Datum target frame*

The datum targets are indicated by a circular frame divided in two compartments by a horizontal line. The lower compartment is reserved for a letter and a digit. The letter represents the datum feature and the digit the datum target number.

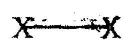
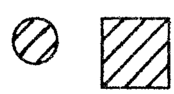
The upper compartment is reserved for additional information, such as dimensions of the target area. If there is not sufficient space within the compartment, the information may be placed outside and connected to the appropriate compartment by a leader line.

FIGURE 32 - Datum target frame

The datum target frame is connected to the datum target symbol by a leader line, terminated by an arrow.

18.1.2 *Datum targets*

If the datum target is

- a point : it is indicated by a cross X
- a line : it is indicated by two crosses, connected by a thin continuous line 
- an area : it is indicated by a hatched area surrounded by a thin double dashed chain line. 

The symbols shall be placed on that view of the drawing, which most clearly shows the relevant surface (see Figure 36). The locations of the datum targets may be dimensioned on that view which is mot convenient, preferably in a full view.

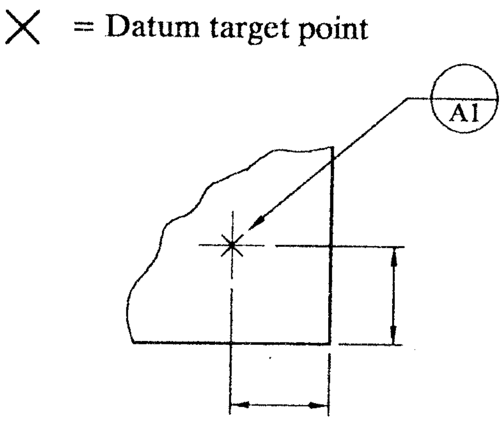


FIGURE 33 - Datum target point

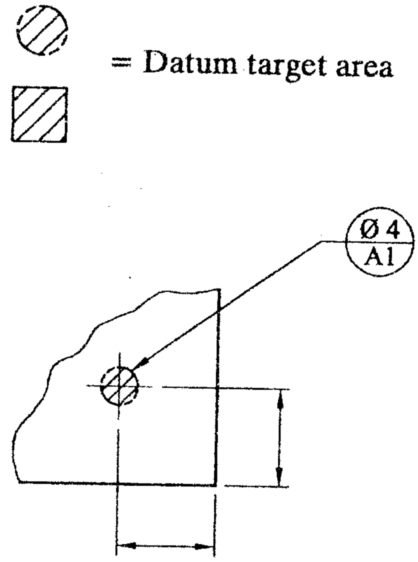


FIGURE 34 - Datum target areas

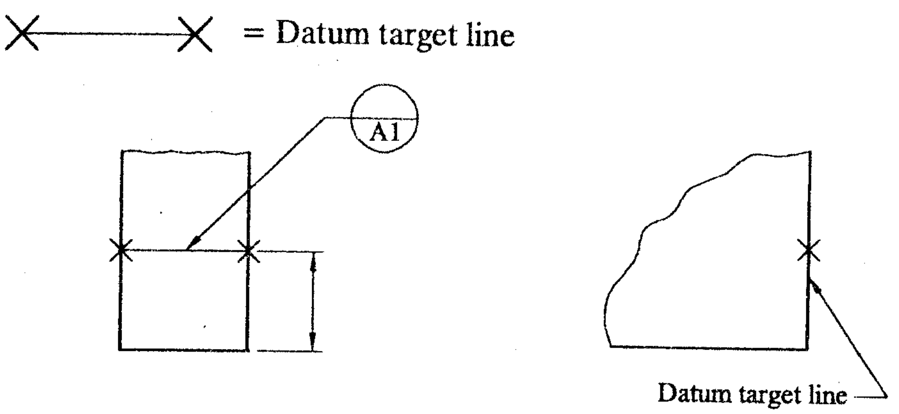


FIGURE 35 - Datum target line

18.2 Application of the datum targets

Interpretation :

Datum targets "A1", "A2" and "A3" establish datum "A"
Datum targets "B1" and "B2" establish datum "B"
Datum target "C1" establishes datum "C"

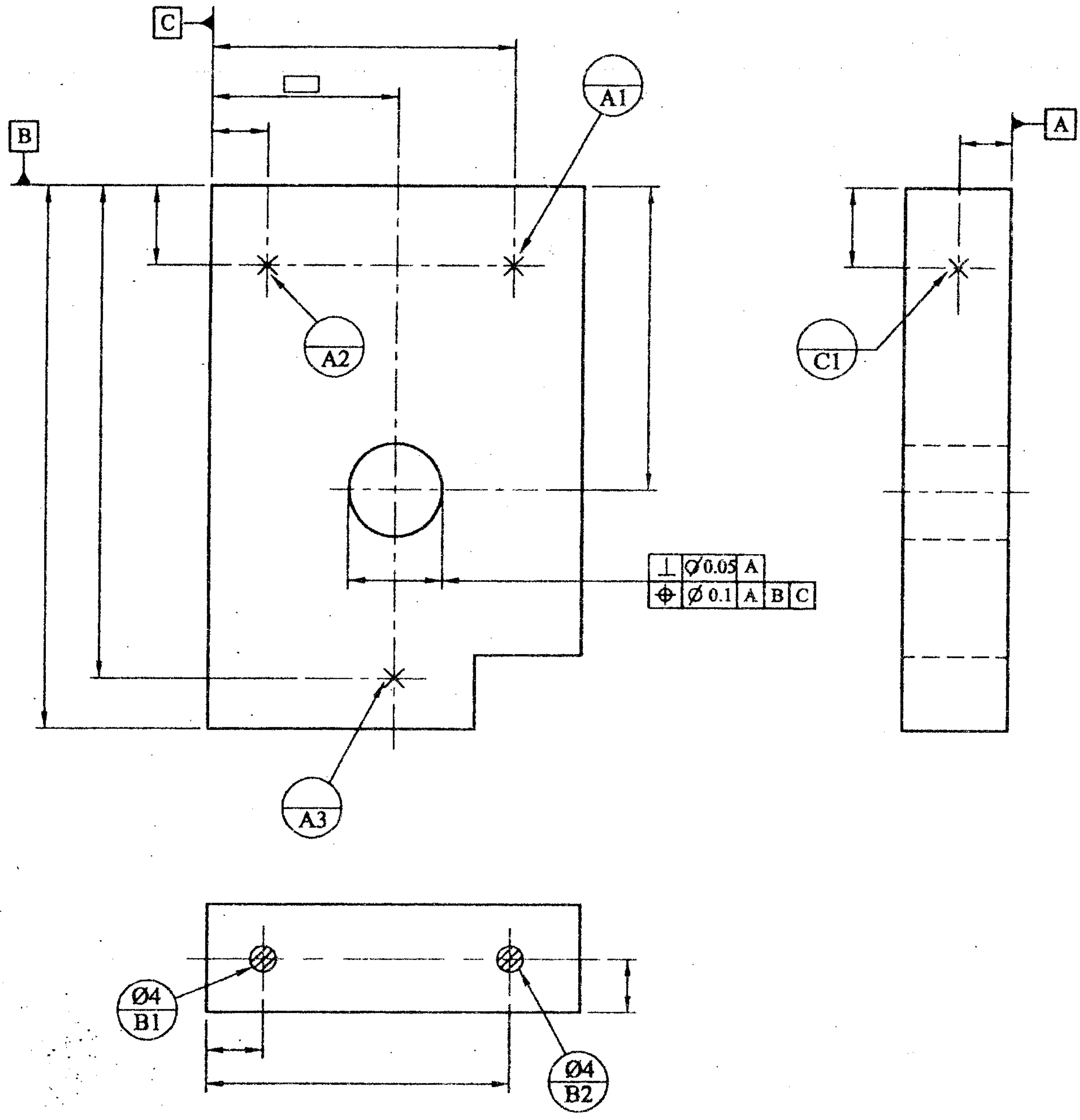
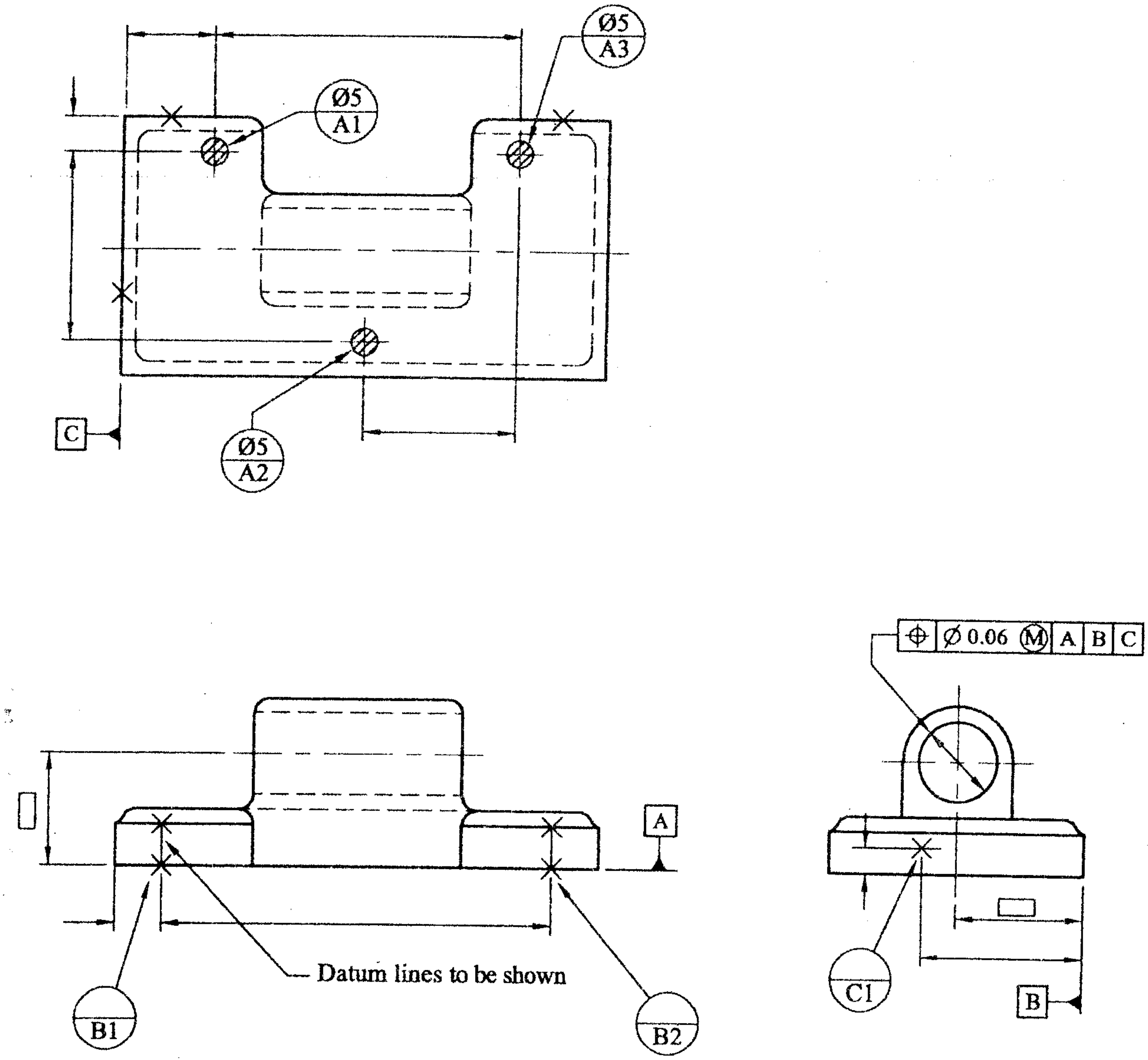


FIGURE 36 - Application of datum targets



Interpretation :

Datum targets "A1", "A2" and "A3" establish datum "A"
Datum targets "B1" and "B2" establish datum "B"
Datum target "C1" establishes datum "C"

FIGURE 37 - Application of datum targets

19. MAXMUM MATERIAL PRINCIPLE

19.1 General

The assembly of parts depends on the relationship between the actual size and actual geometrical deviation of the features being fitted together, such as the boltholes in two flanges and the bolts securing them.

The minimum assembly clearance occurs when each of the mating features is at its maximum material size (eg. largest bolt and smallest hole) and when their geometrical deviations (eg. positional deviation) are also at their maximum.

Assembly clearance increases to a maximum when the actual sizes of the assembled features are furthest from their maximum material sizes (eg smallest shaft and largest hole) and when the geometrical deviations (eg. positional deviations) are zero.

From the above, it follows that if the actual size of a mating part does not reach their maximum material size, the indicated geometrical tolerance may be increased without endangering the assembly of the other part.

This is called the "maximum material principle" and is indicated on drawings by the symbol Ⓜ

The use of maximum material principle facilitates manufacture without disturbing the free assembly of parts where there is a mutual dependence of size and geometry.

The figures in this international Standard are intended only as illustrations to aid the user in understanding the maximum material principle. In some instances, figures show added details for emphasis; in other instances, figures have deliberately been left incomplete. Numerical values of dimensions and tolerances have been given for illustrative purposes only.

For simplicity, the examples are limited to cylinders and planes.

19.2 Least Material Requirement (LMR)

This is closely related to the maximum material principle and is used in controlling minimum wall thickens, preventing breakout, etc.

The least material requirement permits an increase in the stated geometrical tolerance when the concerned feature departs from its least material condition (LMC) (see Appendix A for illustration of least material requirement)

It is indicated on drawings by the symbol Ⓛ placed in the tolerance frame after the tolerance of the toleranced feature or after the datum letter; it specified,

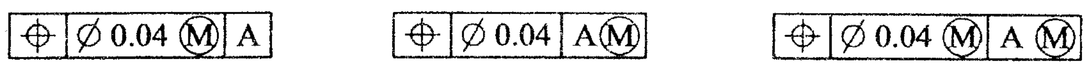
- when applied to the toleranced feature, that the least material virtual condition (LMVC) shall be fully contained within the material of the actual toleranced feature.

- when applied to the datum, that the boundary of perfect form at least material size may float within the material of the actual datum feature without violating the actual datum feature surface.

Examples of the application of the least material requirement (LMR) are given in Appendix **B.**

19.3 Methods of indication

When the maximum material principle is to be applied to a toleranced feature the symbol Ⓜ should be positioned after the tolerance value in the tolerance frame (see Figure **38(a)**). When the maximum material principle is to be applied to a datum feature the symbol should be positioned after the identifying letter in the tolerance frame (see Figure **38(b)**). When both conditions apply, this should be indicated as in Figure **38(c)**.



(a) (b) (c)

FIGURE 38 - Indication of maximum material principle

NOTES

1) When applied to the toelranced feature(s), the maximum material principle permits an increase in the stated geometrical tolerance when the toleranced feature concerned departs from its maximum material condition provided that the feature does not violate the virtual conditions.

*2) When the maximum material principle is applied to the datum feature(s), the datum axis or medium plane may float is relation to the toleranced feature if their is a departure. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size (see Figure **64(b) and 64(c)**).*

The departure of the datum feature from its maximum material size does not increase the tolerance of the toleranced features in relation to each other.

19.4 Application of the maximum material principle

19.4.1 *General*

In all cases, the design has to decide the application of the maximum material principle may be permitted on the tolerances concerned.

NOTE: *The maximum material principle should not be used in such applications as kinematics linkages, gear centres, threaded holes, interference fit holes etc., where the function may be endangered by increase in the tolerance*

19.4.2 *Relationship to geometrical form*

Since the maximum principle involves a relationship between size and form, or size and position, it can only apply to those features where this relationship is possible. The feature may be the feature being toleranced and/or the datum feature depending on each design requirement. In effect this limits its application to features of size incorporating an axis or a media plane with the following toleranced characteristics:

a) straightness;
b) parallelism;
c) perpendicularity;
d) angularity;
e) position;
f) concentricity;
g) symmetry

19.4.3 *Positional tolerance for a group of holes*

The maximum material principle is most commonly used with positional tolerances, and therefore positional tolernacing has been used for the illustrations in this sub-clause.

NOTE: *In the calculations of virtual size, it has been assumed that the pins and holes are at their maximum material size and are of perfect form.*

19.4.3.1. The indication of the drawing of the positional tolerance for a group of four holes is shown in Figure **39**.

The indication on the drawing of the positional tolerance for a group of four fixed pins, which fit into the group of holes, is shown in Figure **41**.

The minimum size of the holes is Ø 8.1 – this is the maximum material size.

The maximum size of the pins is Ø 7.9 – this is the maximum material size.

19.4.3.2 The difference between the maximum size of the holes the pins is $8.1 - 7.9 = 0.2$

The sum of the positional tolerances for the holes and pins shall not exceed this difference (0.2), In this example, this tolerance equally distributed between holes and pins, i.e. the positional tolerance for the holes is 0.1 (see Figure **39**) and positional tolerance for the pins is also 0.1 (see Figure **41**).

The tolerance zones of **Ø** 0.1 are located at their theoretically exact positions (see Figures **40** and **42**)

Depending on the actual size of each feature, the increase in the positional tolerance may be deferent for each feature.

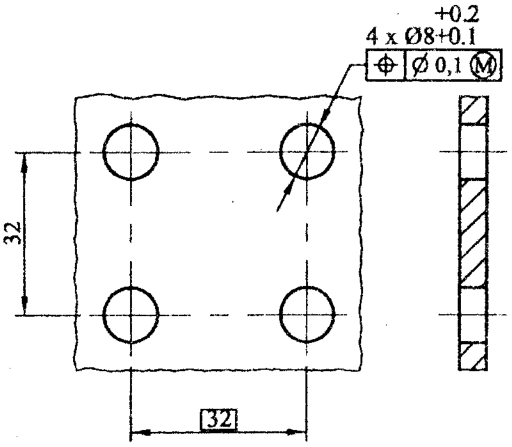


FIGURE 39 - Drawing indication for holes

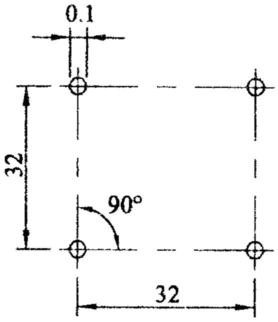


FIGURE 40 - Tolerance diagram for the axis of the holes at maximum material size

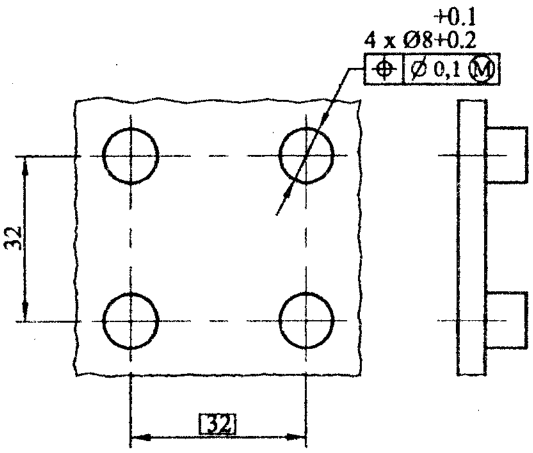


FIGURE 41 - Drawing indication for fixed pins

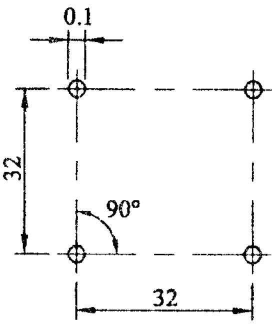


FIGURE 42 - Tolerance diagram for the axis of the pins at maximum material size

19.4.3.3 Figure **43** shows four cylindrical surfaces for each of the four holes all being at their maximum material size and of perfect form. The axes are located extreme positions within the tolerance zone.

Figure **45** shows the corresponding pins at their maximum material size. It can be seen form figures to that assembly of the parts is still possible under the most unfavorable conditions.

(a) One of the holes in Figure **43** is shown to a larger scale in Figure **44**. The tolerance zone for the axis is 0.1. The maximum material size of the hole is Ø 8.1. All Ø 8.1 circles, the axes of which are located at the extreme limit of the Ø 0.1 tolerance zone, from an inscribed enveloping cylinder of Ø 8. This Ø 8 enveloping cylinder is located at the theoretically exact position and forms the functional boundary for the surface of the hole.

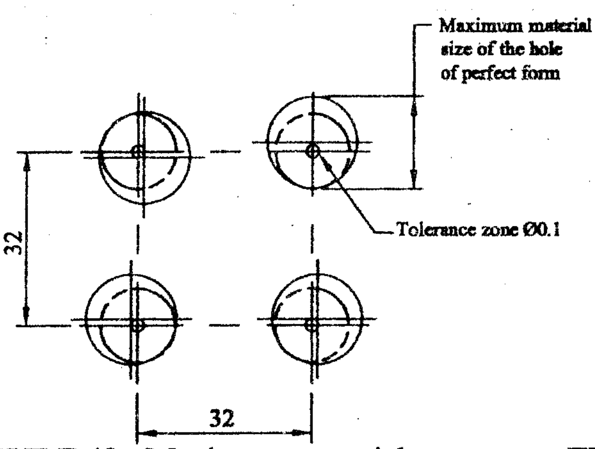


FIGURE 43 - Maximum material size of hole

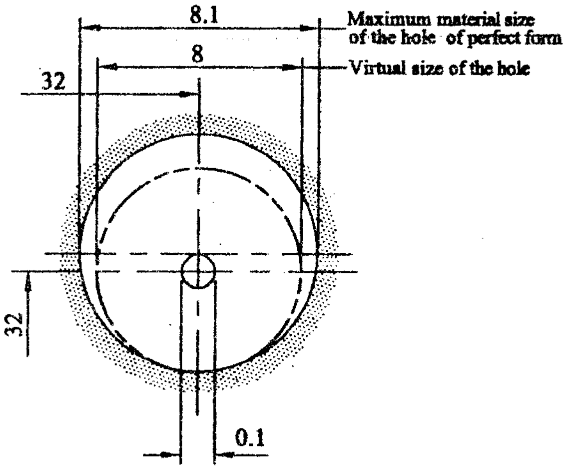


FIGURE 44 - Maximum material size of the hole (in a large scale)

(b) One of the pins in Figure **45** is shown to a larger scale in Figure **46.** The tolerance zone for the axis is 0.1. The maximum material size of the pin is Ø 7.9. All Ø 7.9 circles, the axes of which are located at the extreme limit of the Ø 0.1 tolerance zone, form a circumscribed enveloping cylinder of Ø 8, which is the virtual condition of the pin.

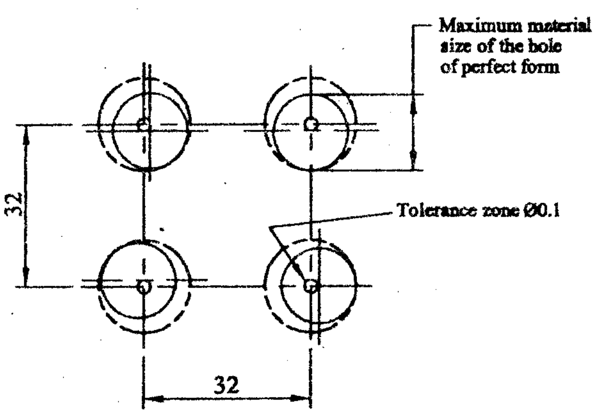


FIGURE 45 - Maximum material size of pin

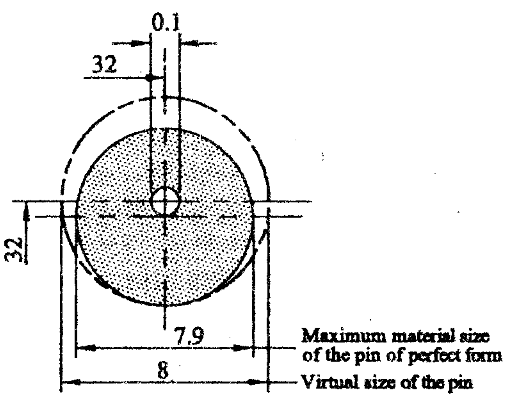


FIGURE 46 - MMS of the pin in a large scale

19.4.3.4 When the size of the hole is larger than its maximum material and/or when the size of the pin is smaller than its maximum material size, there is an increased clearance between the pin and hole, which can be used to increase the positional tolerances of the pin and/or the hole. Depending on the actual size of each feature, the increase in the positional tolerance may be different for each feature.

The extreme case is when the hole is at the least material size, i.e Ø 8.2. Figure **47** shows that the axis of the hole may lie any where within tolerance zone of Ø 0.2, without the surface of the hole violation the cylinder of virtual size.

Figure **48** shows a similar situation with regard to the pins. When the pin is at the least material size, i.e Ø 7.8, the diameter of the tolerance zone for position is Ø 0.2.

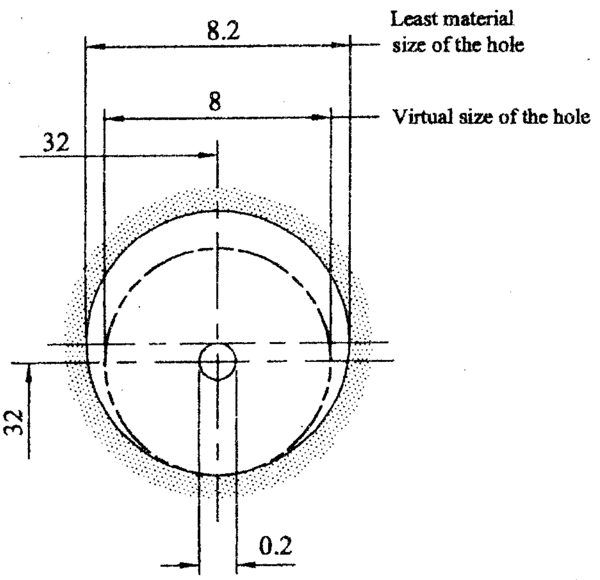


FIGURE 47 - Least material size of the hole

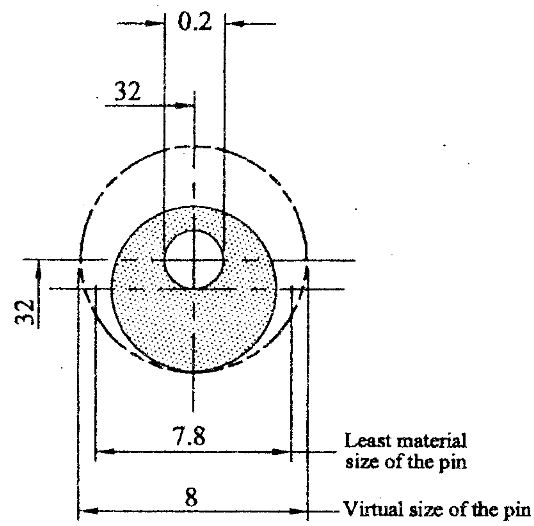
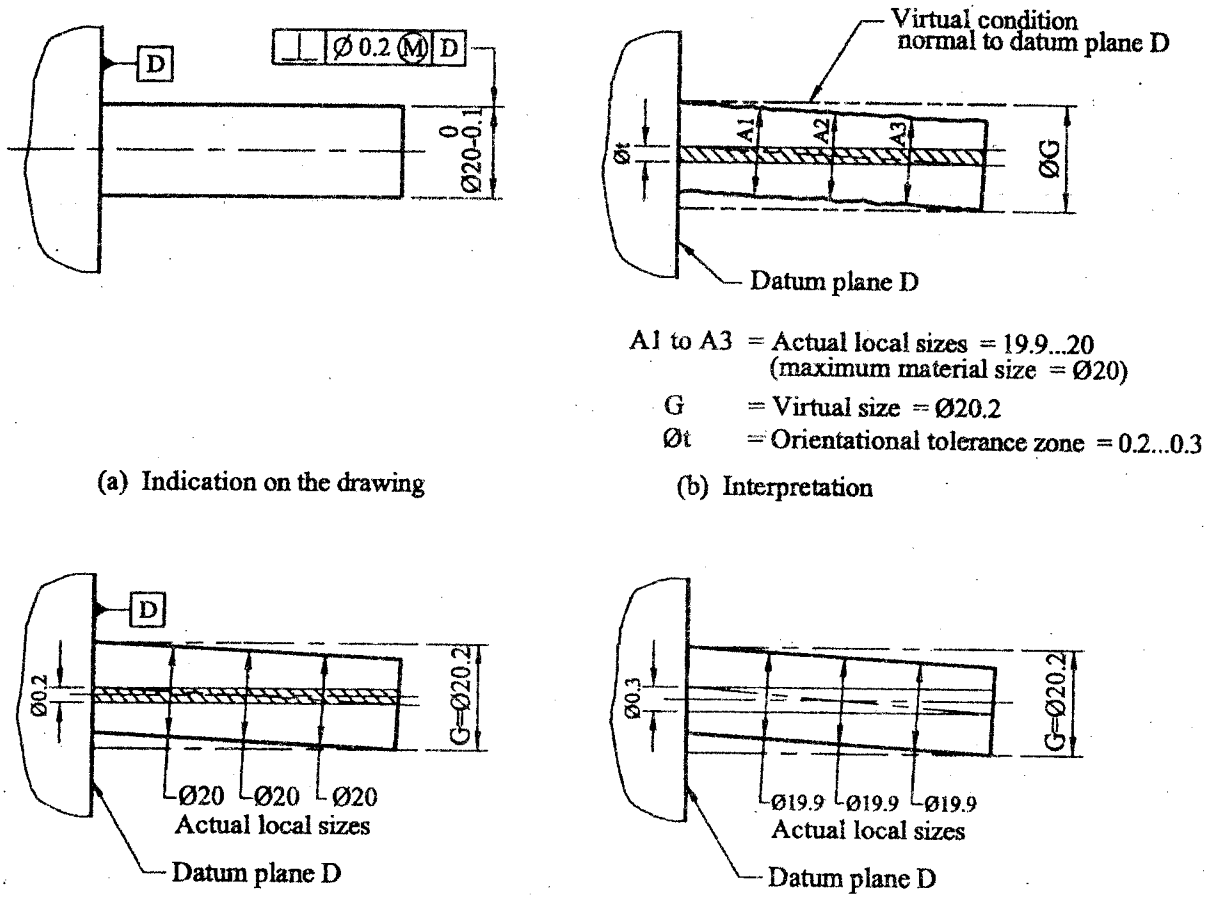


FIGURE 48 - Least material size of the pin

19.4.3.5 The increase in geometrical tolerance is applied to one part of the assembly without reference to the mating part. Assembly will always be possible even when the mating part is manufactured on the extreme limits of the tolerance in the direction most unfavorable for the assembly, because the combined deviation of size and geometry on neither part is exceed, i.e their virtual conditions are not violated.

19.4.4 ***Perpendicularity tolerance of a shaft related to a datum plane.***

19.4.4.1 The toleranced feature in Figure **49(a)** has to meet the conditions shown in Figure **49(b),** i.e the feature shall not violate the virtual condition, i.e 20.2 (20 + 0.2), and as all actual local size shall remain between 19.9 and 20, the straightness deviations of the generator lines or of the axis cannot exceed 0.2.....0.3 depending on the actual sizes, e.g 0.2 if all actual local size are 20 (see Figure **49(c)**) and 0.3 if all actual local size are 19.9 (see Figure **49(d)**).



(a) Indication on the drawing

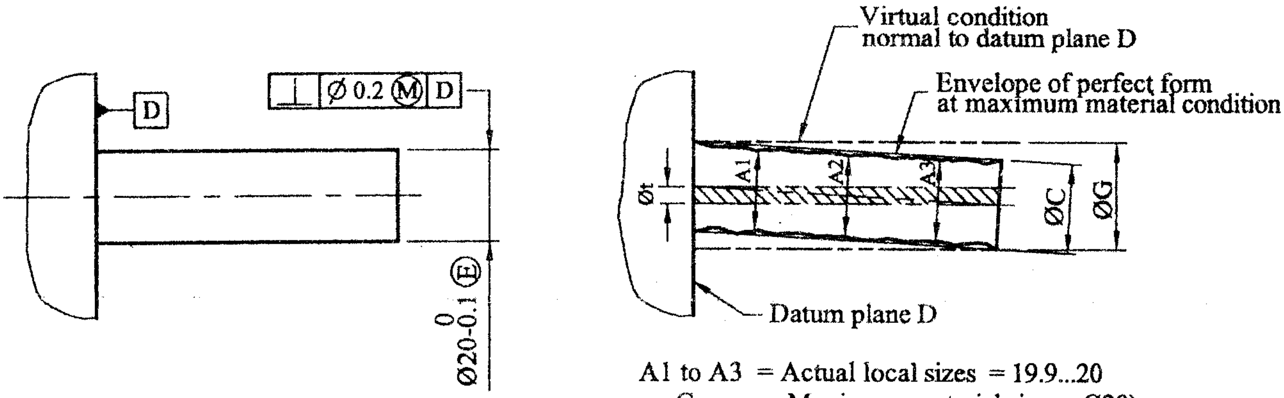
(b) Interpretation

(c) Straightness deviations

(d) Straightness deviations

FIGURE 49 - Perpendicularity tolerance with independency of size and form

19.4.4.2 In Figure **50(a)** the additional requirement Ⓔ together with Ⓜ further restricts the feature to lie within the envelope of perfect form at maximum material size 20 (see Figure **50(b)**). In this example, the actual local size shall remain within 19.9 and 20 and the combined effect of the straightness and roundness deviations shall not cause the feature to violate the envelope requirement. For example, the straightness deviation of the generator lines or of the axis cannot exceed 0...0.1 depending on the actual local size; however the perpendicularity deviation, because of the Ⓜ indication, may be increased to 0.3 virtual size (= 20.1) when the actual local size of the feature are 19.9 (see Figure **50(b)**).



A1 to A3 = Actual local sizes = 19.9...20
C = Maximum material size = Ø20)
G = Virtual size = Ø20.2
Øt = Orientational tolerance zone = 0.2...0.3

(a) (b)

FIGURE 50 - Envelope requirement specified with perpendicularity tolerance

19.5 Examples of application where Ⓜ applies to the toleranced feature(s)

19.5.1 *Straightness tolerance of an axis*

a) Indication on the drawing

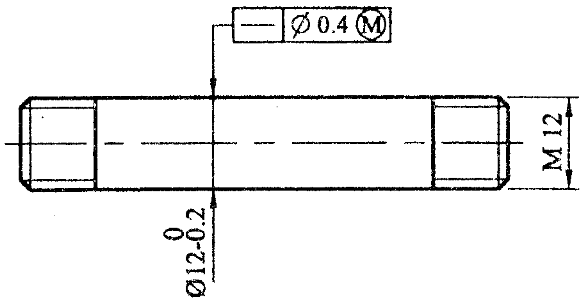


FIGURE 51(a) - Straightness tolerance of an axis

b) Functional requirements

The toleranced feature shall meet the following requirements:

- each actual local size of the feature shall remain within the size tolerance of 0.2 and therefore may vary between 12 and 11.8;

- the toelranced feature shall comply with the virtual condition, i.e the enveloping cylinder of perfect form of 12.4 (= 12+ 0.4) (see Figures **51(b)** and **51(c)**).

The axis shall , therefore, remain within the straightness tolerance zone of 0.4 when all diameters of the feature are at their maximum material size of 12 (see Figure **51(b)**) and may vary within a tolerance zone of up to 0.6 when all diameters of the feature are at their least material size of 11.8 (see Figure **51(c)**).

NOTES

1. *The two Figures 51(b) and 51(c) illustrate the extreme cases of the size of the feature,. In practice, the feature would be somewhere between the extreme conditions with different actual local sizes.*

2. *This indication (see Figure 51(a)) may be appropriate when the indication of a greater diameter tolerance associated with the envelope requirement cannot be applied, e.g in the case of a threaded bolt.*

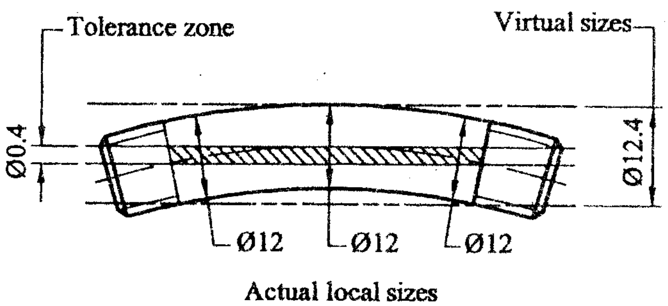


FIGURE 51(b) - Shaft of maximum matetial size

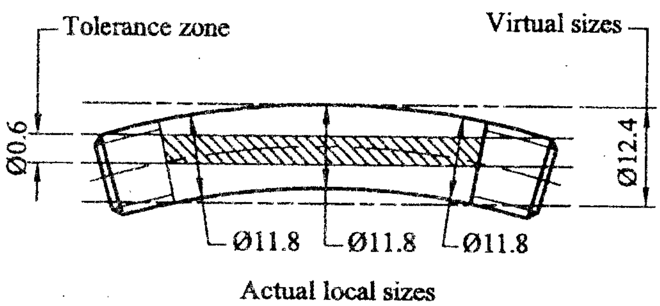


FIGURE 51(c) - Shaft of least matetial size

19.5.2 ***Parallelism tolerance of a shaft related to a datum plane***

a) Indication on the drawing

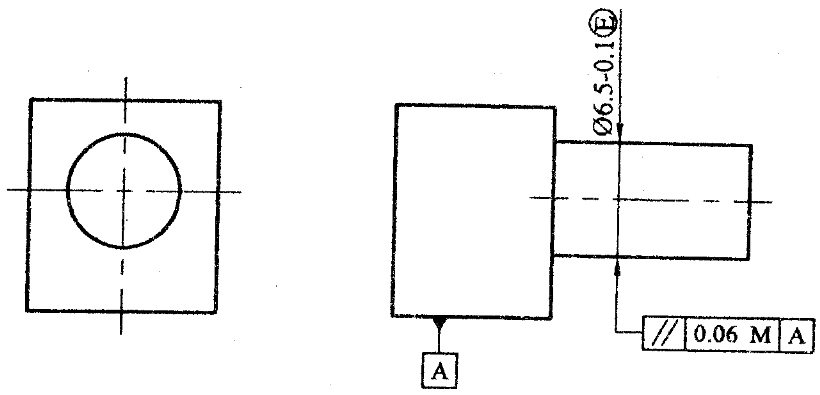


FIGURE 52(a) - Indication on the drawing

b) Functional requirement

The toleranced feature shall meet the following requirements:

- each actual local size of the feature shall remain within the size tolerance of 0.1 and therefore may vary between Ø 6.5 and Ø 6.4;

- the entire feature shall remain within the boundary of the enveloping cylinder of perfect form of Ø 6.5;

- the toleranced feature shall comply with the virtual condition established by two parallel planes 6.56 (= 6.5 + 0.06) apart and parallel to the datum plane A (see Figure **52(b)** and **52(c)**).

NOTES

1 *In the case of a parallelism tolerance of an axis to a datum plane, the tolerance zone has to be a zone between two parallel planes and cannot be a cylindrical tolerance zone.*

2 *As the parallelism tolerance zone is a zone between parallel planes, the virtual condition is a zone between two parallel planes. The distance between them is the maximum material size 6.5 plus the parallelism tolerance of 0.06, i.e 6.56.*

The conditions of the perfect cylinder at maximum material size, as indicated by Ⓔ *has to be checked separately.*

3 *The two Figure 52(b) and 52(c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local size.*

3 The two Figure 52(b) and 52(c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local size.

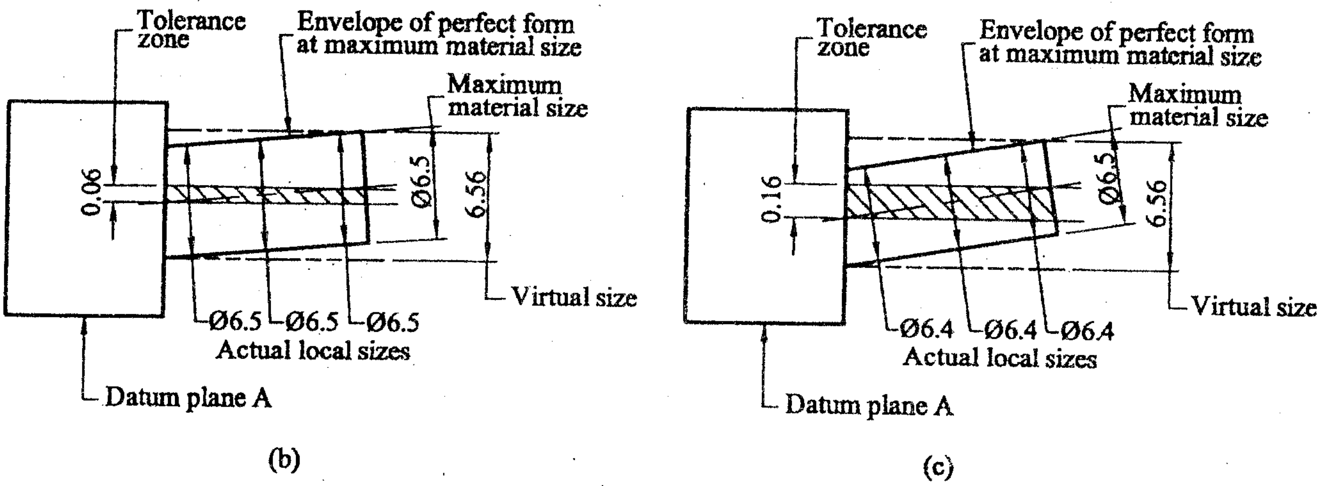


FIGURE 52 - Extreme cases of parallelism tolerance of a shaft

19.5.3 ***Perpendicularity tolerance of a hole related to a datum plane.***

a) Indication on the drawing

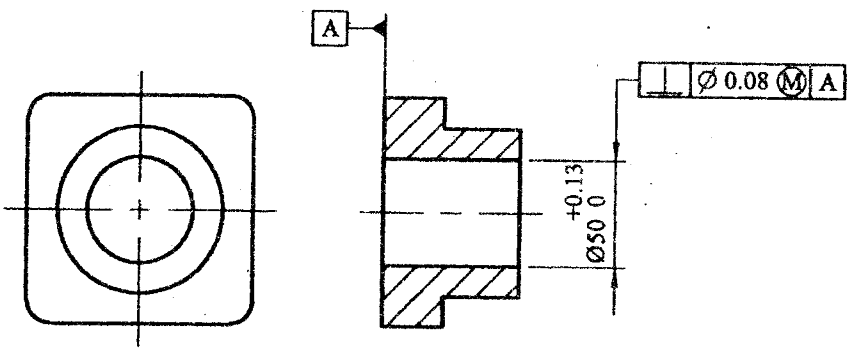


FIGURE 53(a) - Perpendicularity tolerance of a hole

b) Functional requirements

The toleranced feature shall meet the following requirements:

- each actual local size of the feature shall remain with the size tolerance of 0.13 therefore any vary between Ø 50 and Ø 50.13;
- the tolerance feature shall comply with the virtual condition boundary, i.e. the inscribed cylinder of perfect form of Ø 49.92 (= 50 – 0.08) and perpendicular to the datum plane A (see Figure **53(b)** and **53(c)**).

The axis shall, therefore, remain with the tolerance zone of 0.08 perpendicular to the datum plane A when all diameters of the feature are at their maximum material size of 50 (see Figure **53(b)**) and may vary within a tolerance zone of up to 0.21 when all diameters of the feature are at their least material size of 50.13 (see Figure **53(c)**).

NOTE: *The two Figures 53(b) and 53(c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local size.*

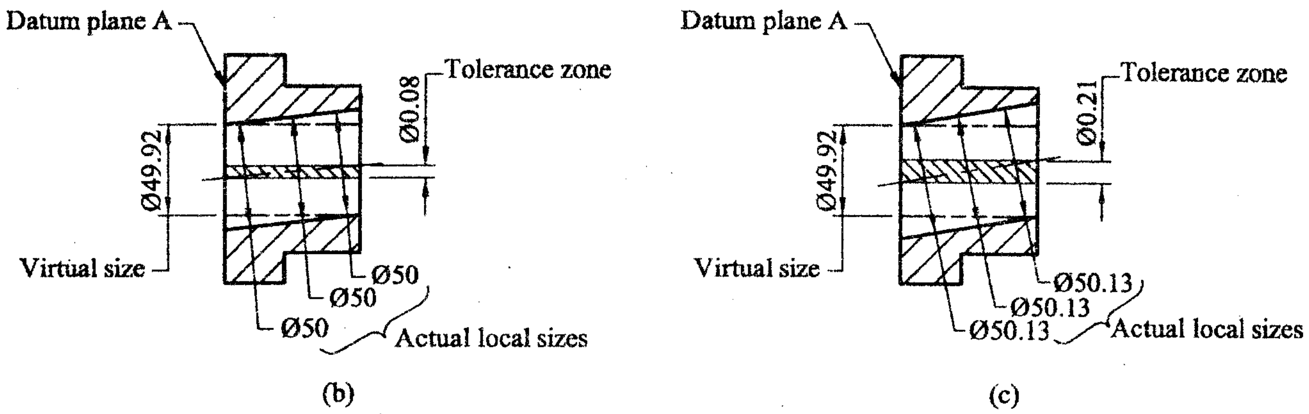


FIGURE 53 - Perpendicularity tolerance of a hole

19.5.4 *Angularity tolerance of a slot related to a datum plane*

a) Indication on the drawing

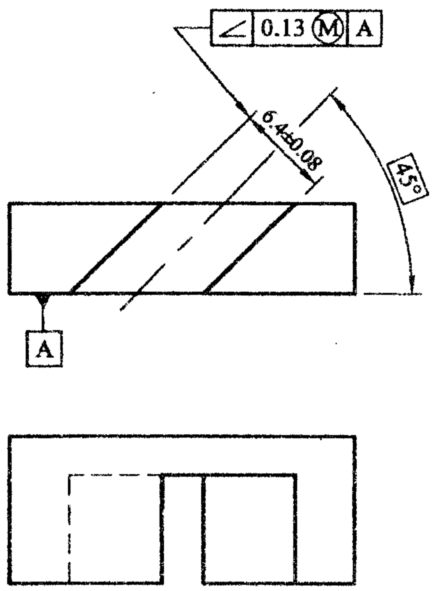


FIGURE 54(a) - Angularity tolerance of a slot

b) Functional requirements

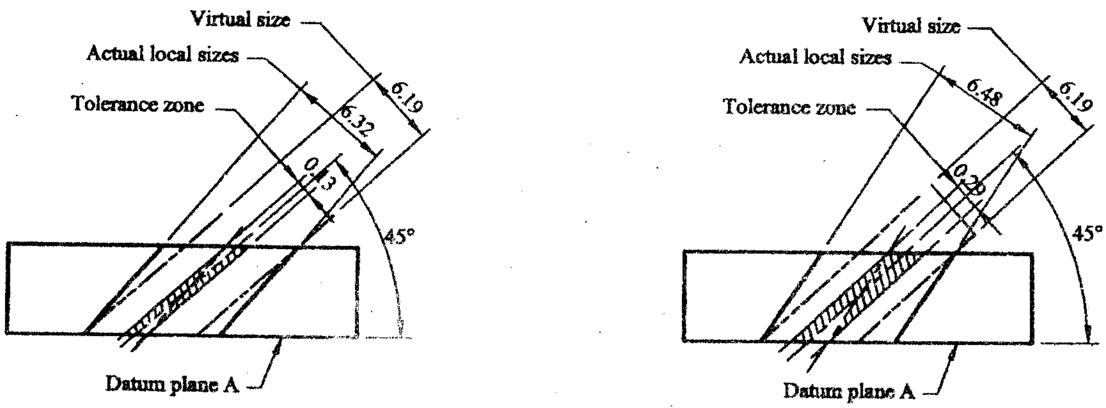
The toleranced featured shall meet the following requirements :

- each actual local size of the feature shall remain within the size tolerance of 0.16 and therefore may vary between 6.32 and 6.48;

- the toleranced feature shall comply with the virtual condition boundary established by two parallel planes 6.19 (= 6.32-0.13) apart and at the specified angle of 45 ° to the datum plane A (See Figure **54(a)**).

The median plane of the feature shall, therefore, remain between two parallel planes 0.13 apart, inclined at the specified angle of 45 ° to the datum plane A, when all widths of the feature are at their maximum material size of 6.32 (see Figure **54(b)**). The median plane of the feature may vary within a tolerance zone of up to 0.29 when all widths of the feature are at their least material size of 6.48 (see Figure **54 (c)**).

NOTE: *The two Figures 54(b) and 54(c) illustrate the extreme cases where the feature is of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local sizes.*



(b) (c)

FIGURE 54 - Extreme cases of angularity tolerance of a slot

19.5.5 ***Positional tolerance of four holes related to each other***

a) Indication on the drawing

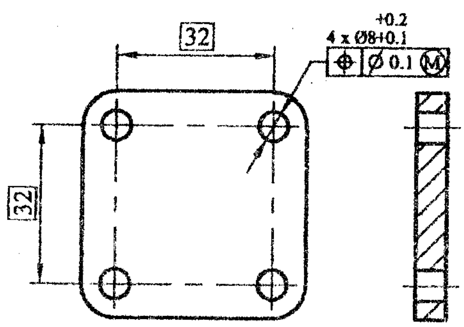


FIGURE 55(a) - Positional tolerance of four holes related to each other

b) Functional requirements

The toleranced features shall meet the following requirements:

- each actual local size of each feature shall remain within the size tolerance of 0.1 and each may vary between Ø 8.1 and Ø 8.2;

- all toleranced features shall comply with the virtual condition boundary, i.e the inscribed cylinder of perfect form of Ø 8. 9= (Ø 8.1 – 0.1), where each of these cylinders is located its theoretically exact position in relation to the other cylinders (dimensions 32 in an exact 90 ° pattern) (see Figure **55 (a)**).

The axis of each feature shall, therefore, remain within the positional tolerance zone of 0,1 when each diameter of the feature is at its maximum material size of Ø 8.1 (see Figure **55(b)**) and may vary within a tolerance zone of 0.2 when each diameter of the feature is at its least material size of Ø 8.2 (see Figure **55(c)**).

NOTE: *The two Figures 55(b) and 55(c) illustrate the extreme cases where the features are of theoretically exact form. In practice, the feature would be somewhere between the extreme conditions with different actual local size.*

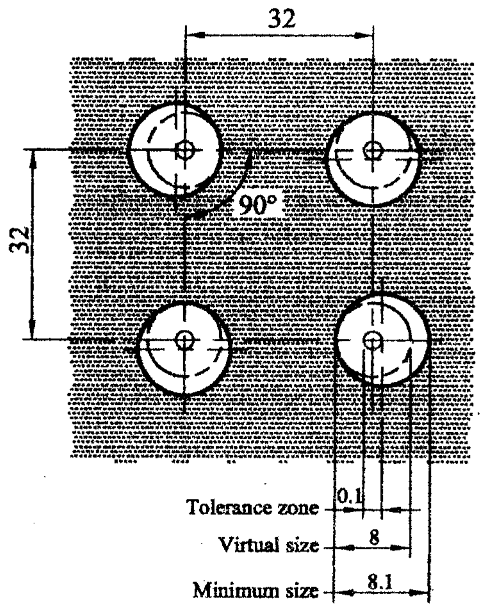


FIGURE 55(b) - Positional tolerance zone maximum material size

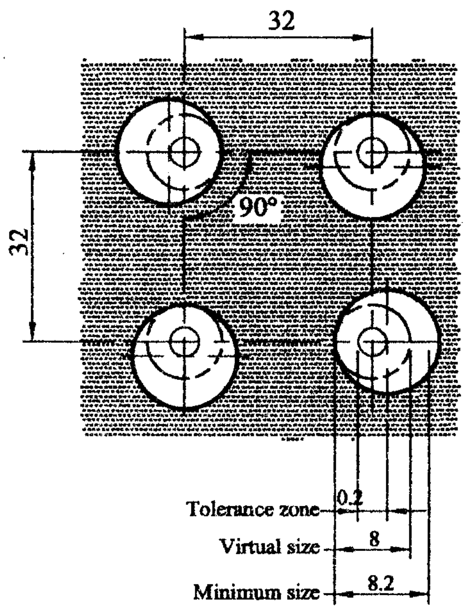


FIGURE 55(c) - Positional tolerance least material size

The dynamic tolerance diagram (see Figure **56**) illustrates the interrelation between the feature size and the permissible deviation from theoretically exact position according to Table **4.**

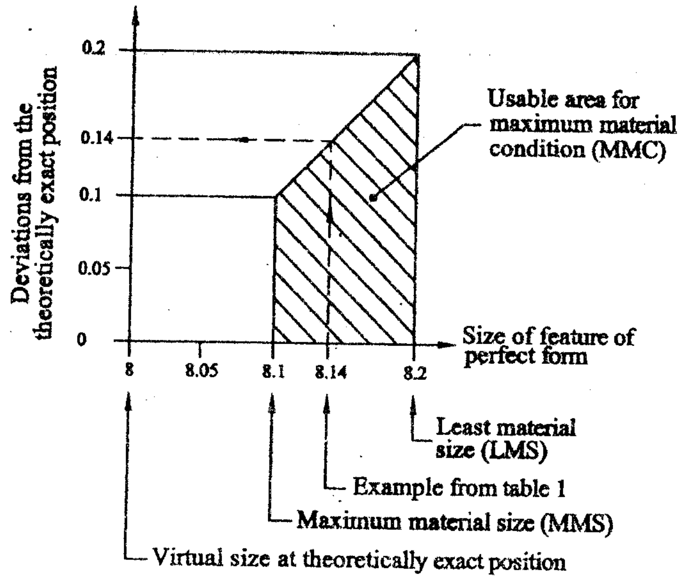


FIGURE 56 - Dynamic tolerance diagram

TABLE 4 - Deviation from the theoretically exact positron

Diameter of hole of perfect form	Positional tolerance
8.10 MMS	0.10
8.12	0.12
8.14	0.14
8.16	0.16
8.18	0.18
8.2 LMS	0.20

The functional gauge (see Figure 56) represents the virtual condition.

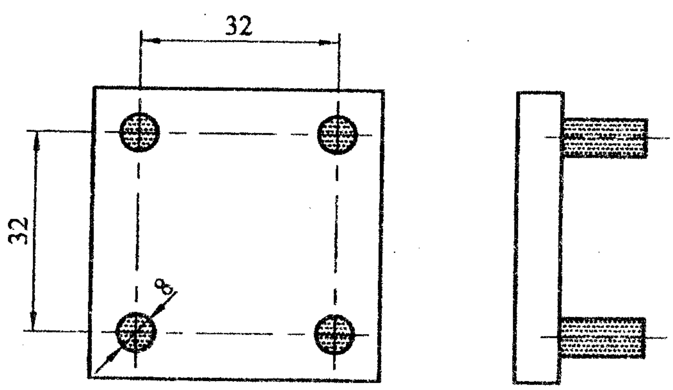


FIGURE 57 - The functional gauge

19.6 Zero geometrical tolerancing

19.6.1 *General*

In the examples given in **5.1** and **6.5** the tolerance is distributed between size and position. The extreme case is to allocate the total tolerance to the size and to indicate a zero positional tolerance. In this case, the size tolerance is increased and becomes the sum of the size and positional tolerance indicated previously.

The indication on the drawing for the holes in Figure **39**, therefore becomes as illustrated in Figure **57(a)** and the indication on the drawing for the pins in Figure **41** therefore becomes as illustrated in Figure **57(b)**.

According to the indications on the drawings in Figure **58 (a)** and **58 (b)**, the positional tolerances may vary between Ø 0 and Ø 0.2 as the actual sizes vary between maximum and minimum.

The indication"0Ⓜ "may also be used with other geometrical characteristics.

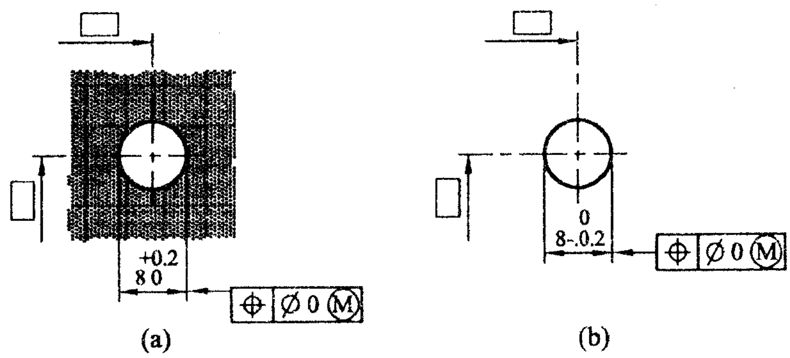


FIGURE 58 - Zero geometrical tolerancing

19.6.2 *Examples*

19.6.2.1 Four holes related to each other

a) Indication on the drawing

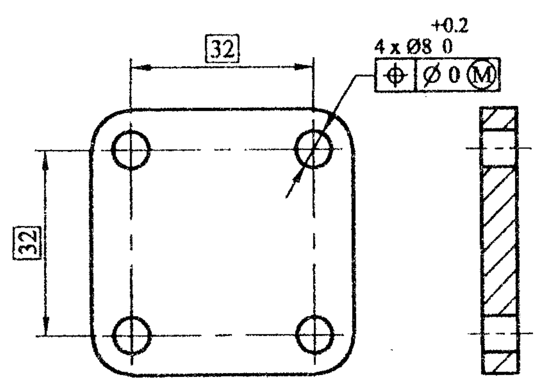


FIGURE 59 - Four holes related to each other

b) Interpretation

According to the indication on the drawing in Figure 59, the virtual size is the maximum material size (minimum hole diameter) minus the given positional tolerance, i.e Ø 8- Ø 0 = Ø 8.

The dynamic tolerance diagram (see Figure 60) illustrates the interrelation between the feature size and the permissible deviation from the theoretically exact positron according to Table 5.

TABLE 5 - Deviation from the theoretically exact positron

Diameter of hole of perfect from	Positional tolerance
8.00 MMS	0
8.04	0.04
8.08	0.08
8.12	0.12
8.16	0.16
8.20	0.20

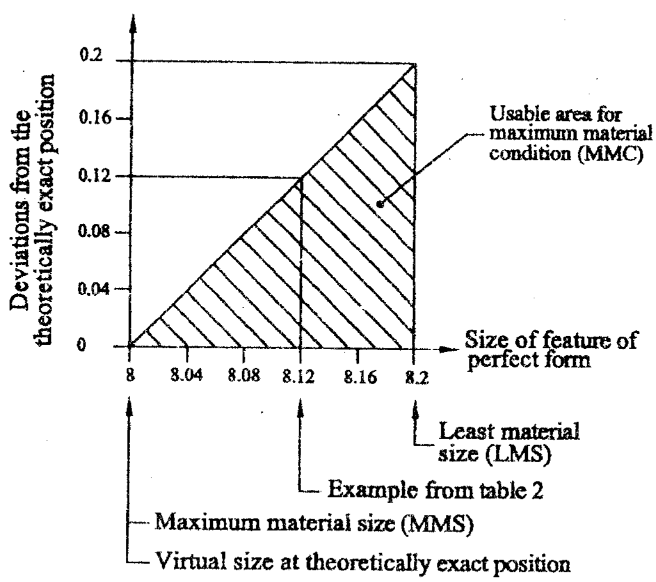


FIGURE 60 - The dynamic tolerance diagram

The functional gauge in accordance with Figure 57 also represents the virtual condition of the part illustrated in Figure 59. In both cases, the feature diameters shall be checked separately according to their different size tolerances.

19.6.2.2 Four pins related to each other

a) Indication on the drawing

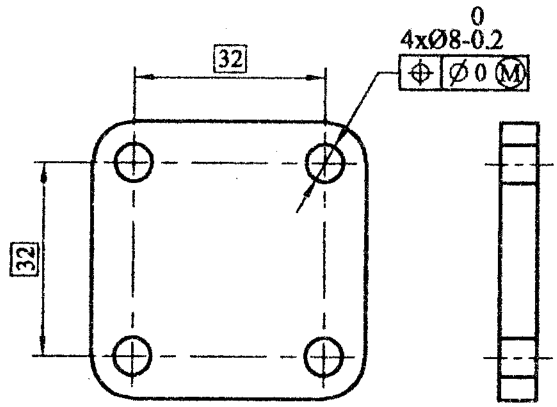


FIGURE 61 - Indication on the drawing

b) Interpretation

According to the indication on the drawing in Figure **61** the virtual size is the maximum material size (maximum pin diameter) plus the given positional tolerance, i.e Ø 8 + Ø 0 = Ø 8.

The dynamic tolerance diagram (see Figure **62**) illustrates the interrelation between the feature size and the permissible deviation from the theoretically exact position according to Table **6.**

TABLE 6- Deviation from the theoretically exact position

Diameter of pin of perfect form	Positional tolerance
8.00	0.00
7.96	0.04
7.92	0.08
7.88	0.12
7.84	0.16
7.80	0.20

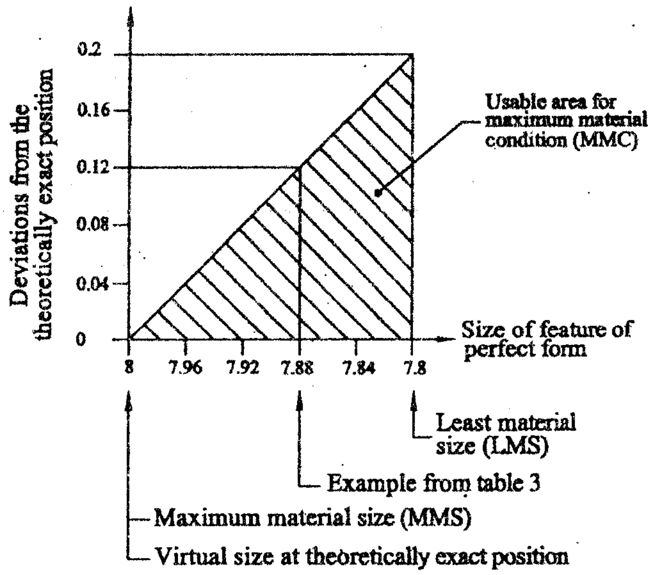


FIGURE 62 - The dynamic tolerance diagram

The functional gauge (see Figure 63) represent the virtual condition.

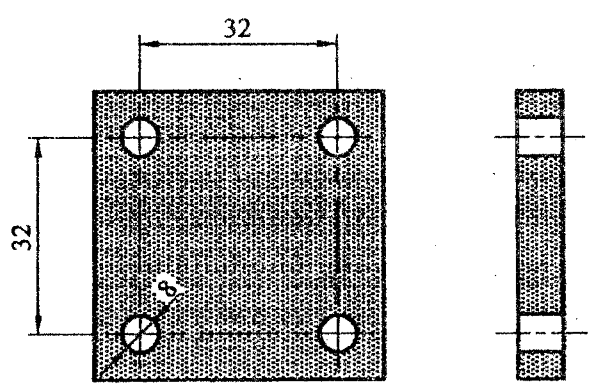


FIGURE 63 - The functional gauge

19.7 Examples of application where Ⓜ applies to the toleranced feature(s) and the datum feature

19.7.1 ***Positional tolerance of four holes related to a datum hole***

a) Indication the drawing

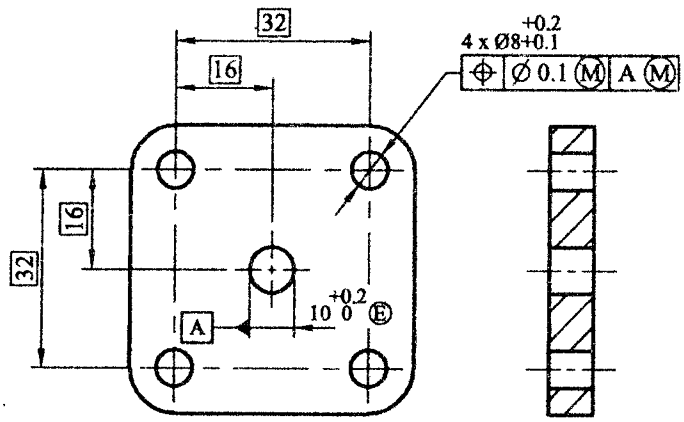


FIGURE 64(a) - Positional tolerance of four holes related to a datum hole

c) Functional requirements

The toleranced feature shall meet the following requirements :

- Each actual local size of each feature shall remain within the size tolerance of 0.1 and therefore amy vary between Ø 8.1 and 8.2 (see Figure **64(b)** and Figure **64(c)**).

- All toleranced features shall comply with the virtual condition boundary, i.e the inscribed cylinder of perfect form of Ø 8 (= Ø 8.1 – 0.1), where each of these cylinder is located in its theoretically exact position in relation to the other cylinders (dimensions 32) in an exact 90° pattern , (see Figure **64(b))** and Figure **64(c)**) and also in its theoretically exact position in relation to the datum axis when the mating size of the datum feature A is at the maximum material size of Ø 10 (see Figure **64 (b)**).

  In the extreme case, the axis of each feature shall, therefore, remain within the positional tolerance zone of Ø 0.1 when each feature diameter is at its maximum material size of Ø 8.1 (See Figure **64(b)**) and may vary within a tolerance zone of Ø 0.2 when each feature diameter is at its least material size of Ø 8.2 (see Figure **64(c)**).

- The actual axis of the datum feature A may float in relation to the virtual conditions of the position of the four features if there is a departure from the maximum material size of the datum feature. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size (see Figure **64(b)** and **64(c)**).

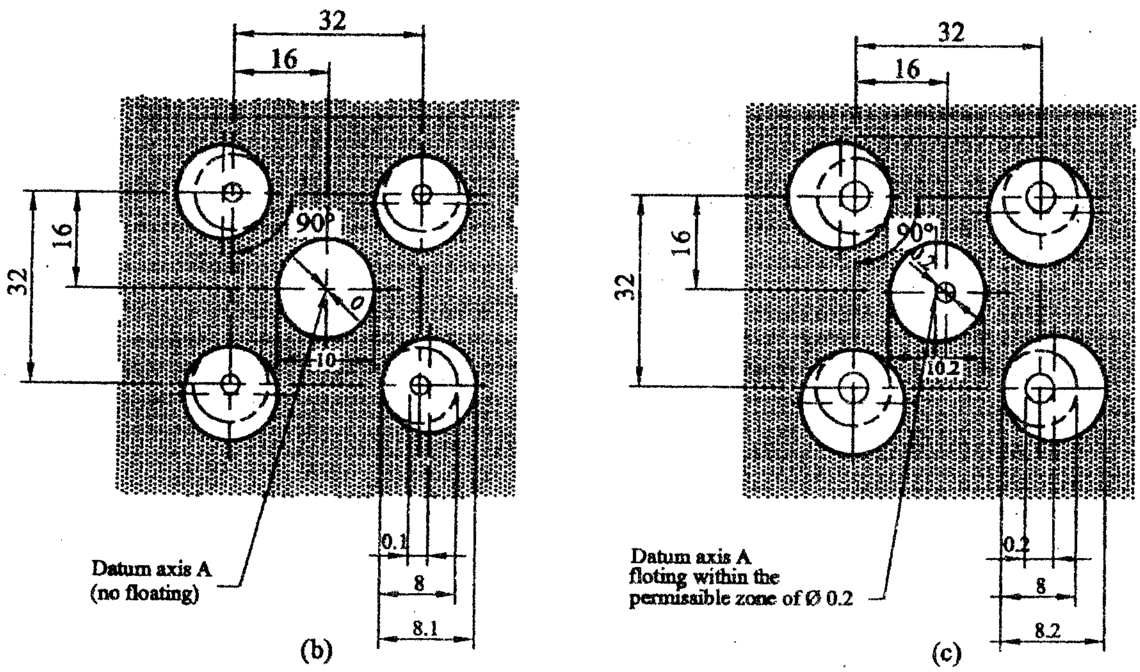


FIGURE 64 - The datum feature from its maximum material size

The positional tolerance applies to the four tolerances relation to each other as well as in relation to the datum feature. The given value is increased by an amount equal to the departure given in table (second column).

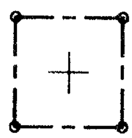
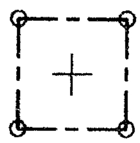
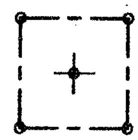
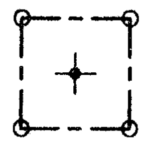
The additional positional tolerance which depends on the size of the datum feature (due to the maximum material condition on the datum) applies only to the toleranced features as a group tolerance in relation to the datum feature, but does not apply to the toleranced features in relation to each other, i.e the datum may float in relation to the toleranced feature (for the values, see Table 7).

TABLE 7- Positional tolerance

Toleranced hole diameter (1)	Positional tolerance of each toleranced feature (2)	Datum hole diameter (3)	Floating zone for datum feature (4)
8.1 MMS	0.1	10 MMS	0.00
8.12	0.12	10.05	0.05
8.14	0.14	10.1	0.10
8.16	0.16	10.15	0.15
8.18	0.18	10.2 LMS	0.20
8.2 LMS	0.20		

Any combination of the values in the second and fourth columns of Table 7 may occur. The values in the second and fourth columns cannot simply be added because they have different interpretations. Some examples of extreme combinations are given in Table **8**.

TABLE 8- Some examples of extreme combinations

Tolerance zone for toleranced feature	0.1	0.2	0.1	0.2
Tolerance zone for datum feature	0	0	0.2	0.2
Tolerance diagram				

The functional gauge (see Figure **65**) represents the virtual condition.

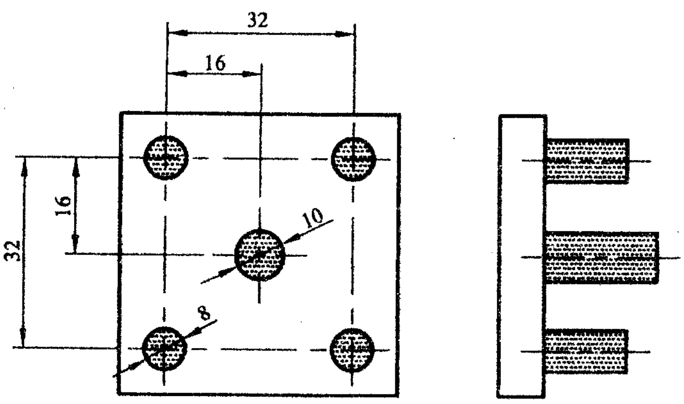


FIGURE 65 - The functional gauge

19.7.2 ***Coaxiality tolerance***

a) Indication on the drawing

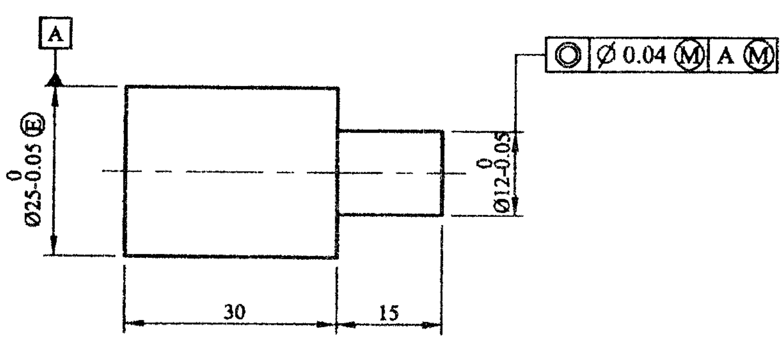


FIGURE 66(a) - Coaxiality tolerance

b) Functional requirements

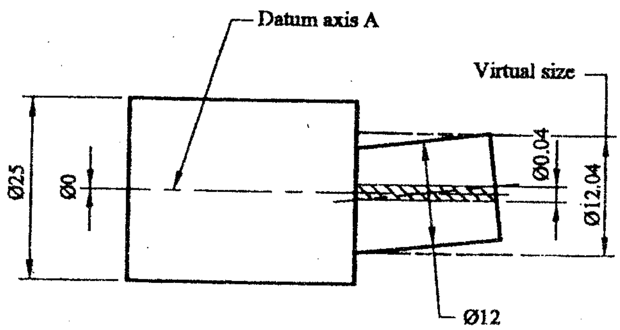
The actual toleranced feature shall meet the following requirements.

- Each actual local size of the feature shall remain within the size tolerance of 0.05 and therefore may vary between Ø 12 and Ø 11.95 (see Figure **66(b)** and **66(c)**).

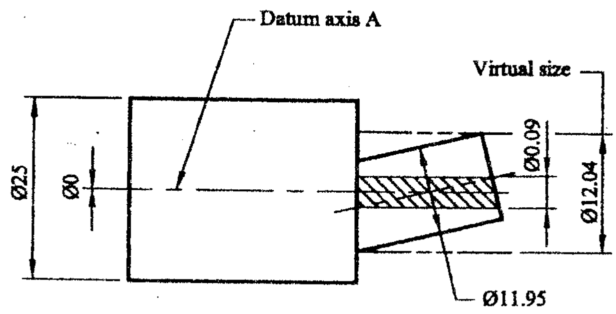
- The whole feature shall remain within the virtual condition boundary, i.e the enveloping cylinder of perfect form of Ø 12,04 (=Ø 12+ 0.04) and coaxial to the datum axis A when the mating size of the datum feature A is at its maximum material size (see Figure **66(b)** and **66(c)**).

- The actual axis of the datum feature A may float in relation to the virtual condition if there is a departure from the maximum material size of the datum feature. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size (see Figure **66(d)**).

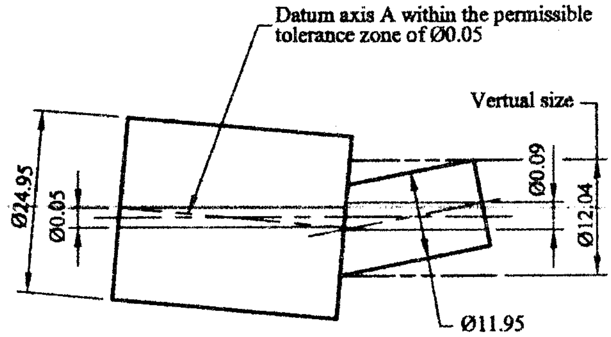
The axis of the feature shall, therefore, remain within the coaxially tolerance zone of 0.04 when all diameters of the feature are at their maximum material size of Ø 12 (see Figure **66(b)**) and may vary within a tolerance zone of up to Ø 0.09when all diameters of the toleranced feature are at their least materials size of Ø 11.95 and the mating sized of the datum feature is at the maximum material size of Ø 25 (see Figure **66(c)**). The actual axis of the datum feature A may float within a zone of 0.05 when the mating size of the datum feature A is at the least material size of Ø 24.95 (see Figure **66 (d)**). As in this case only one feature is related to the datum, the float of the datum has the effect of an increase in the coaxiality tolerance as illustrated in Figure **66(e)**.



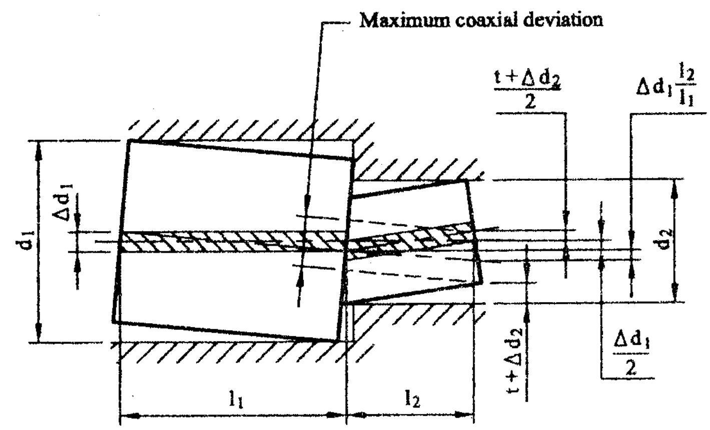
b) When diameters are at their maximum material size



c) When diameters of the feature are at their least material size



d) When the mating size of the datum is at the least material size



Where

d_1 is the maximum material size MMS of the datum feature
d_2 is the virtual size of the toleranced feature
t is the geometrical tolerance
Δd_1 is the minus the mating size of the datum feature
$t+\Delta\ d_2 d_2$ minus the mating size of the tolernaced feature

$$\text{Maximum coaxial deviation} = 2\left(\frac{t+d_2}{2}+\frac{d_1}{2}+\frac{t_2}{t_1}\right)$$

$$= 2\left(\frac{0.04+0.05}{2} + 0{,}025+0{,}05\ \frac{15}{30}\right)$$

$$= 0.19$$

(e) Increase in the coaxiality tolerance

FIGURE 66 - Coaxiality tolerance

The functional gauge (see Figure **(67)**) represents the virtual condition.

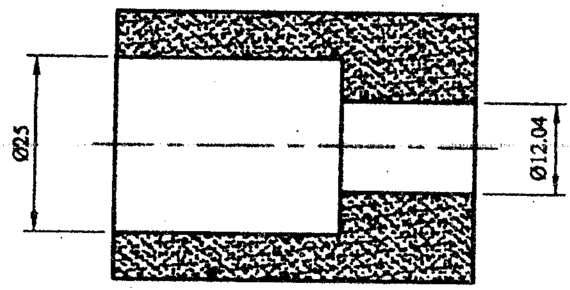


FIGURE 67 - The functional gauge

20 POSITIONAL TOLERANCING

20.1 General

Theoretically exact dimensions and positional tolerances determine the limits of the location of feature, such as points, axes and median planes relative to each other or to one or more datum.

The positional tolerance zone is symmetrically proposed about the theoretically exact location of the feature and its axis is always perpendicular to the primary datum (see Figure **68**)

NOTE: *The concept of positional tolerancing described in item 10 of Table 2 is further elaborated here.*

20.2 Establishment of positional tolerances

20.2.1 *Fundamental requirement*

Positional tolerances are associated with theoretically exact dimensions and define the limits for the location of actual (extracted) features, such as points, axes and median surfaces, nominally straight lines and nominally plane surfaces relative to each other or in relation to one or more datums. The tolerance zone is symmetrically disposed about the theoretically exact location.

NOTE: *The positional tolerances do not accumulate when theoretically exact dimensions are arranged in a chain (see Figure 71). (This contrasts with dimensional tolerances that are arranged in a chain.) Positional tolerancing allows clear reference to be made to one or more datums.*

20.2.2 *Theoritically exact dimensions*

Theoretically exact dimensions, both angular and linear, are indicated by being enclosed in a rectangular frame in accordance with **ISO 1101**. This is illustrated in Figures **69(a)**, **69(a)**, **70(b)**, **71(a)**, **72(a)** and **74(a).**

The theoretically exact dimensions 0°, 180 ° or distance 0 between

- positionally toleranced features not related to a datum (see Figure **71(a)**) and Figure **73(a)**).
- positionally toleranced features related to the same datum(s) Figure **69(a)** and Figure **72(a)**).
- positionally toleranced features and their related to the same datum(s) (see Figure **69(a)**).
- positionally toleranced features and their related datums (see Figure **68**).

are implied without specific indication.

When the positional tolerance features share the same centerline or axis they are regarded as theoretically exactly related features, unless otherwise specified, eg. in relation to different datums or other reason indicated by an appropriate note on the drawing as shown in Figure **69(b)**.

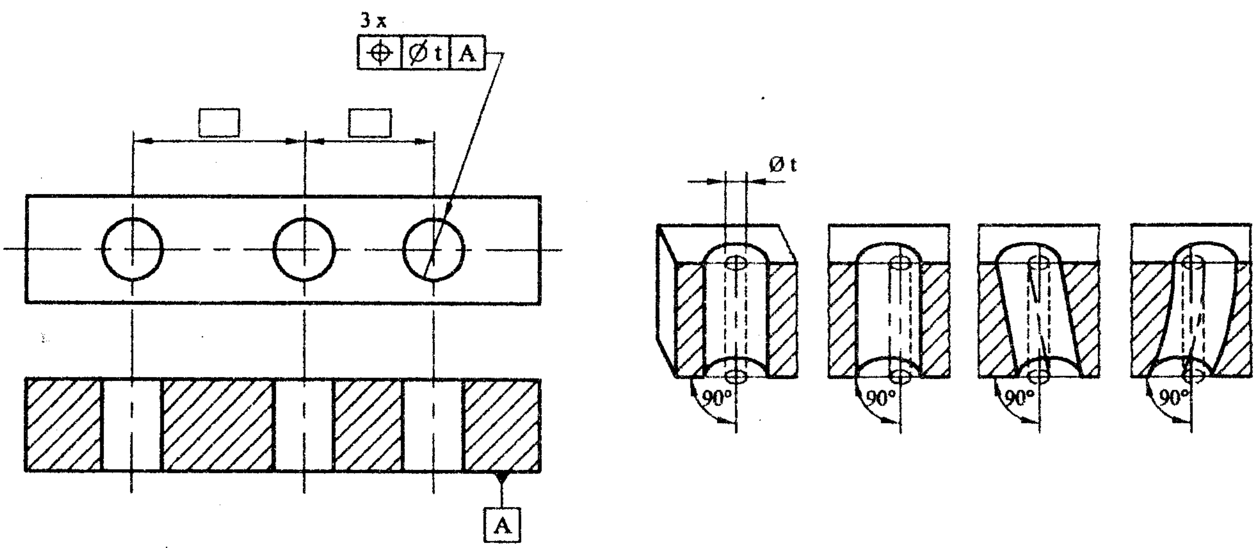


FIGURE 68 - Positional tolerancing

NOTE: *Interpretations a), b), c), d) may apply at each individual hole.*

a) Axis of hole coincident with theoretically exact location (zero deviation).
b) Axis of hole at maximum position deviation with zero perpendicularity deviation.
c) Axis of hole at maximum position deviation with maximum perpendicularity deviation.
d) Axis of hoe at maximum position deviation, in this case a combination of geometrical deviations.

20.2.3 *Positional tolerances on a complete circle*

When positionally toleranced features are arranged in a complete circle, it is understood that the features are equally spaced, unless otherwise stated, and that their locations are theoretically exact.

If two or more groups of features are shown on the same axis, they shall be considered to be a single Pattern when

- they are not related to a datum;
- they are related to the same datum or datum system (datums in the same order of precedence or under the same material conditions) (see Figure **69(a)**). Unless otherwise stated (see Figure **69(b)**).

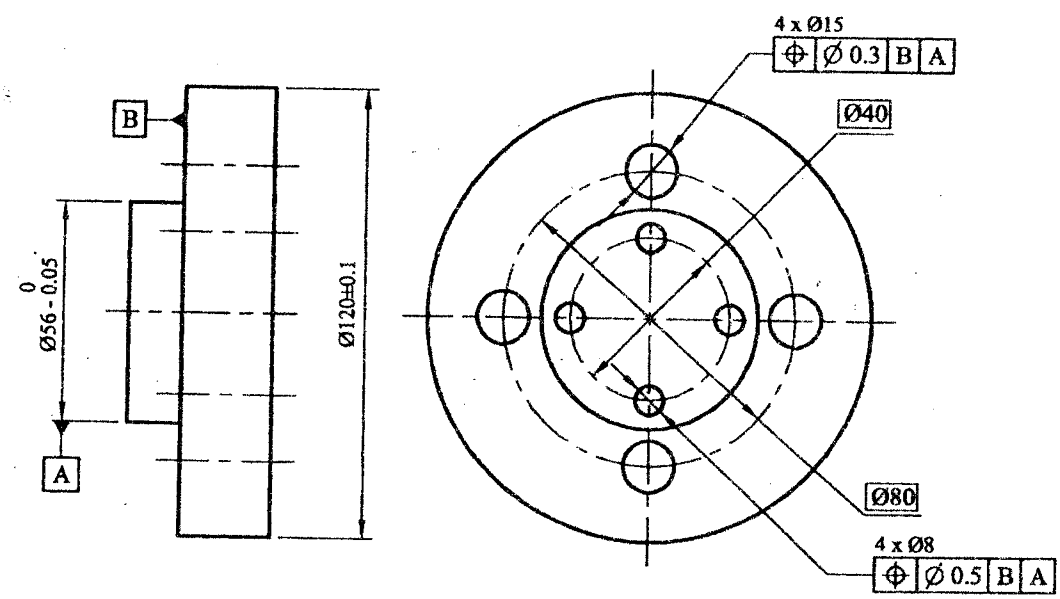


FIGURE 69(a) - Positionally tolerance features related to the same datum

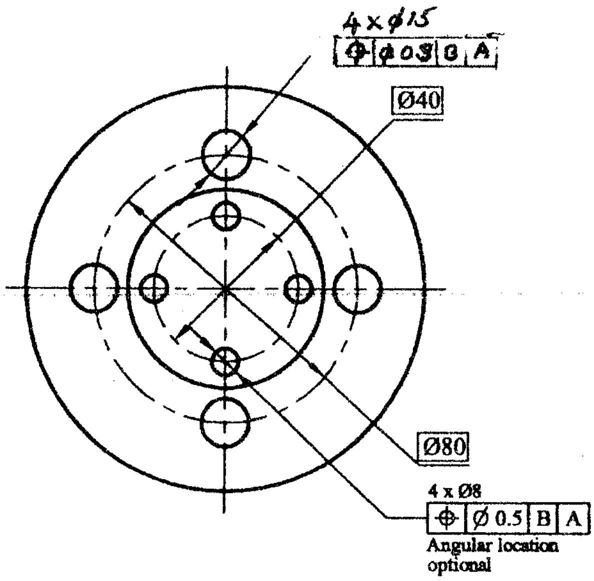
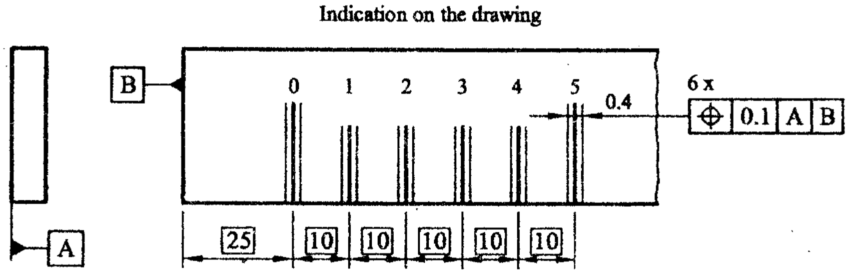


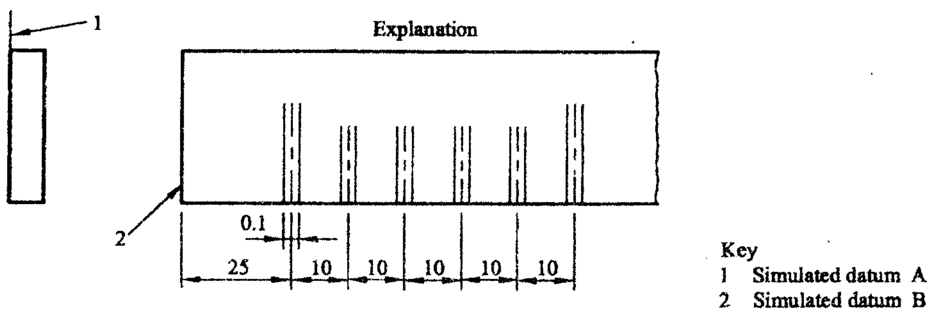
FIGURE 69(b) - Positionally tolerance in one direction only

20.2.4. *Positional tolerances in one direction only*

The tolerance value can be specified in one direction. The orientation of the width of the tolerance is based on the pattern of the theoretically exact dimensions and is at 0° or 90° as indicated by the direction of the arrow line (see Figure **70(a)** and **70(b)**). Unless otherwise indicated.



(a)



(b)

FIGURE 70 - Positional tolerances in one directional only

Each of the scale lines shall be contained within a tolerance zone defined by two parallel straight lines 0.1 apart which are symmetrically disposed about the theoretically exact position of each scale line relative to each other.

20.2.5 *Positional tolerances in two directions*

The tolerance value can be specified in two directions perpendicular to each other, reference being made to unequal values (see Figure 71a) and 71(b)) or equal values.

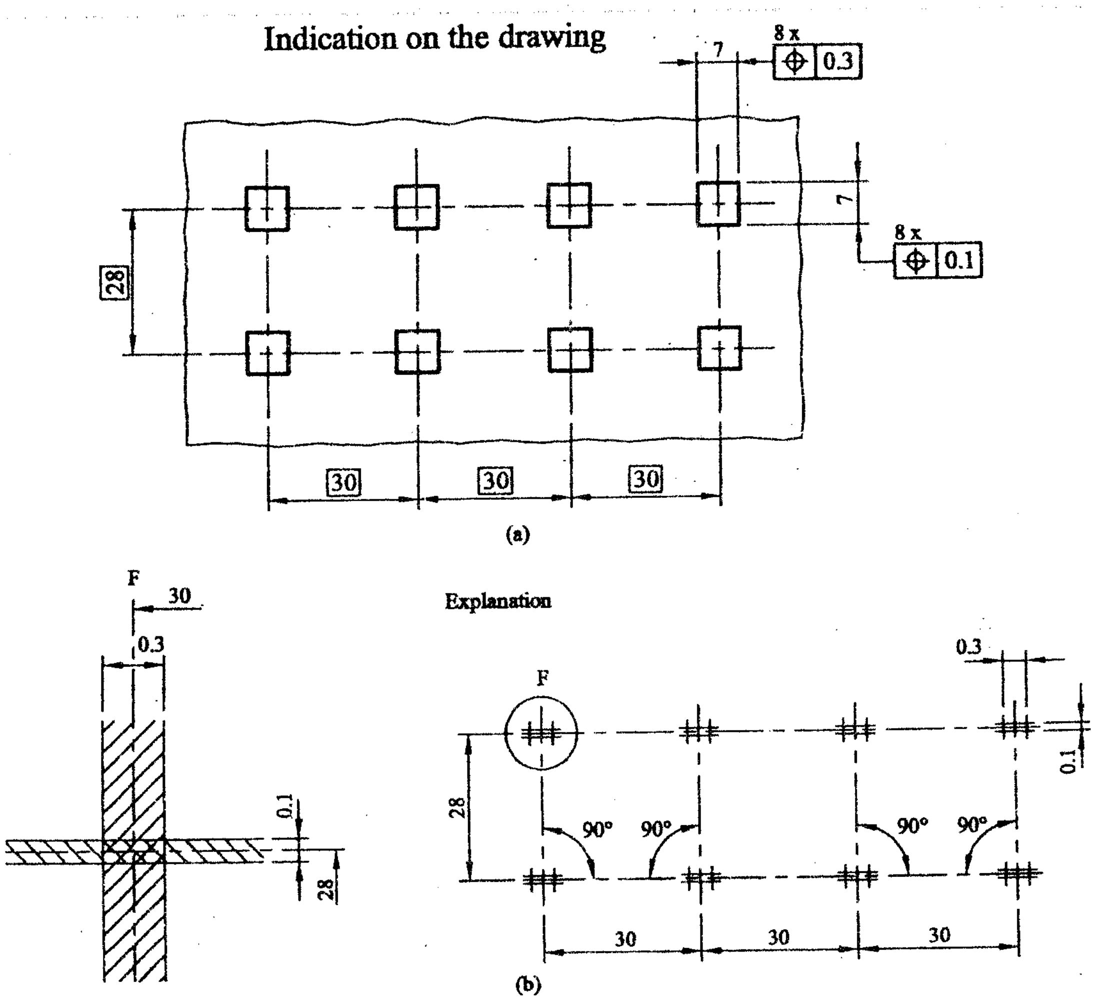


FIGURE 71 - Positional tolerances in two directions

The rectangular pattern consisting of the eight tolerance zones, placed 30 mm apart from each other, is a floating one, the location and orientation of which depends on the considered actual (extracted) features of the work piece.

Each of the holes shall be;

- measured in the direction of the theoretically exact dimension 30; its actual (extracted) median surface lies within a tolerance zone with a rectangular cross section 0.3 x actual length of the feature;
- measured in the direction of the theoretically exact dimensions 28; its actual (extracted) median surface lies within a tolerance zone with a rectangular cross section 0.1 x actual length of the feature.
- the median planes of the tolerance zones are fixed by theoretically exact dimensions.

20.2.6 ***Multi-directional positional tolerances***

The tolerance is be specified as a cylindrical zone (see Figure **72(a)** and **72(b)**). The "rigid rectangular pattern consisting of the eight tolerance zones, placed 30 mm apart form each other, may be implied by a best fit (rotations and translations) to the center point/line data from the actual (exacted) features of the work piece.

Indication on the drawing

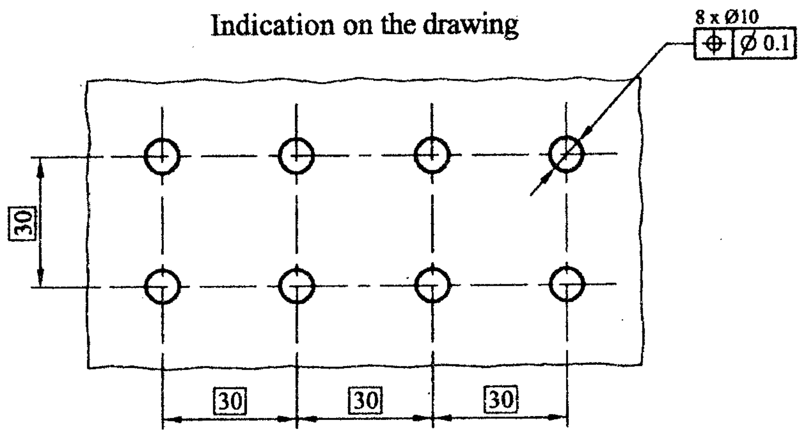


FIGURE 72(a) - Rigid rectangular pattern

The actual (extracted) axis of each hole shall lie within a cylindrical tolerance zone of diameter 0.1 mm; the axes of the cylindrical tolerance zone are fixed by theoretically exact dimensions.

Explanation

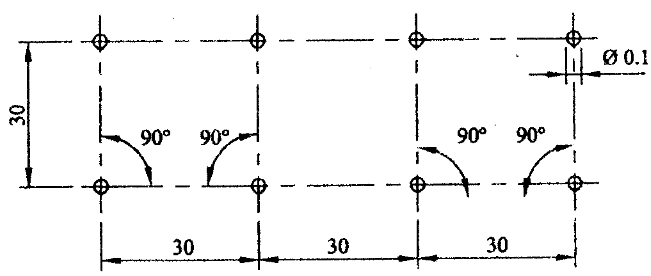


FIGURE 72(b) - Explanation of figure 72(a)

NOTE: *For cylindrical features of mating parts, the tolerance zone is usually cylindrical, as the positional tolerance is multi-directional from the theoretically exact location. In these cases the positional tolerancing method achieves a larger tolerance zone than in the two directions method which can only generate a square (or rectangular) two dimensional tolerance zone; see Figure 72. The choice between "multy directional" and "in two directions" tolerance zone should be made according to the function of the toleranced feature.*

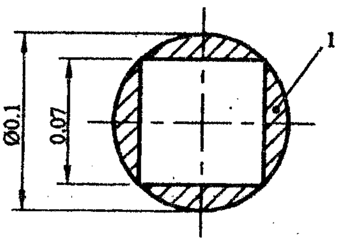


FIGURE 73 - Larger tolerance zone

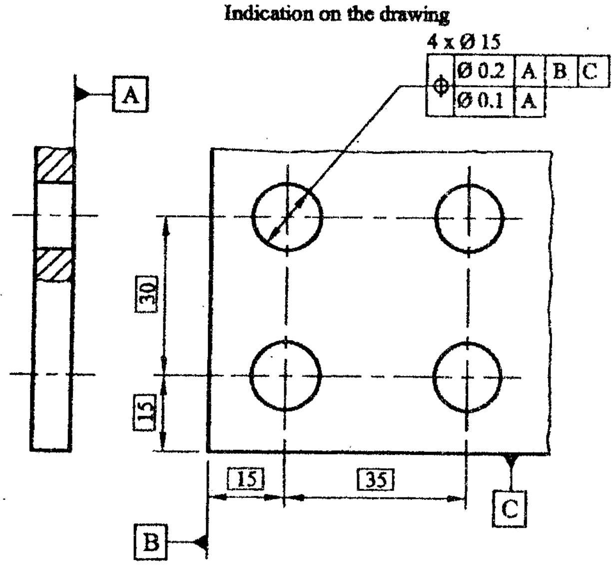
Key
1. 57% larger zone

20.2 Tolerance combinations

20.3.1 If a group of features is individually located by positional tolerancing and their pattern location by coordinate tolerances, each requirement shall be met independently (see Figure **74(a)**).

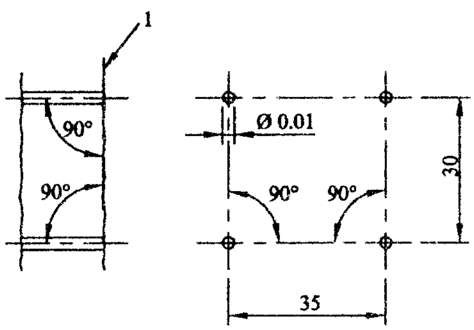
20.3.1.1 The actual (extracted) axis of each of the holes shall lie within the cylindrical tolerance zone of diameter 0.01; the positional tolerance zones are located in their theoretically exact positions to each other and perpendicular to datum A.(Figure **72(b)**).

20.3.1.2 The actual (extracted) axis of each hole shall lie within the cylindrical tolerance zone of diameter 0.2; the positional tolerance zones are located in their theoretical positions in related to each other and to the datums B and C (Figure **70**) exact location to each other (see Figure**74(c)**).



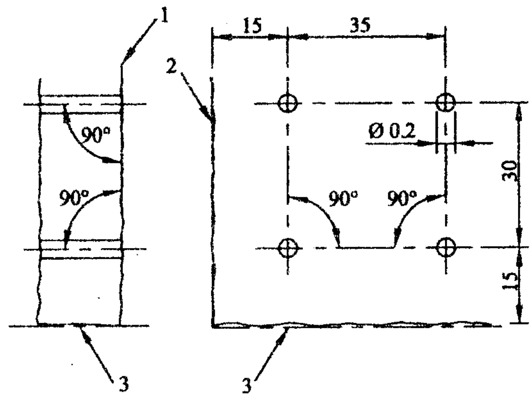
a)

Explanation



Key
1.simulated datum A

(b)



Key
1. simulated datum A
2. simulated datum B
3. simulated datum C

(c)

FIGURE 74 - Tolerance combinations

APPENDIX A

ILLUSTRATION OF THE LEAST MATERIAL REQUIREMENT

The least material requirement is illustrated in Figure 75 ; when the feature departs from its least material size, when it was at perfect form, an increase in positional tolerance is allowed, which is equal to the amount of such departure.

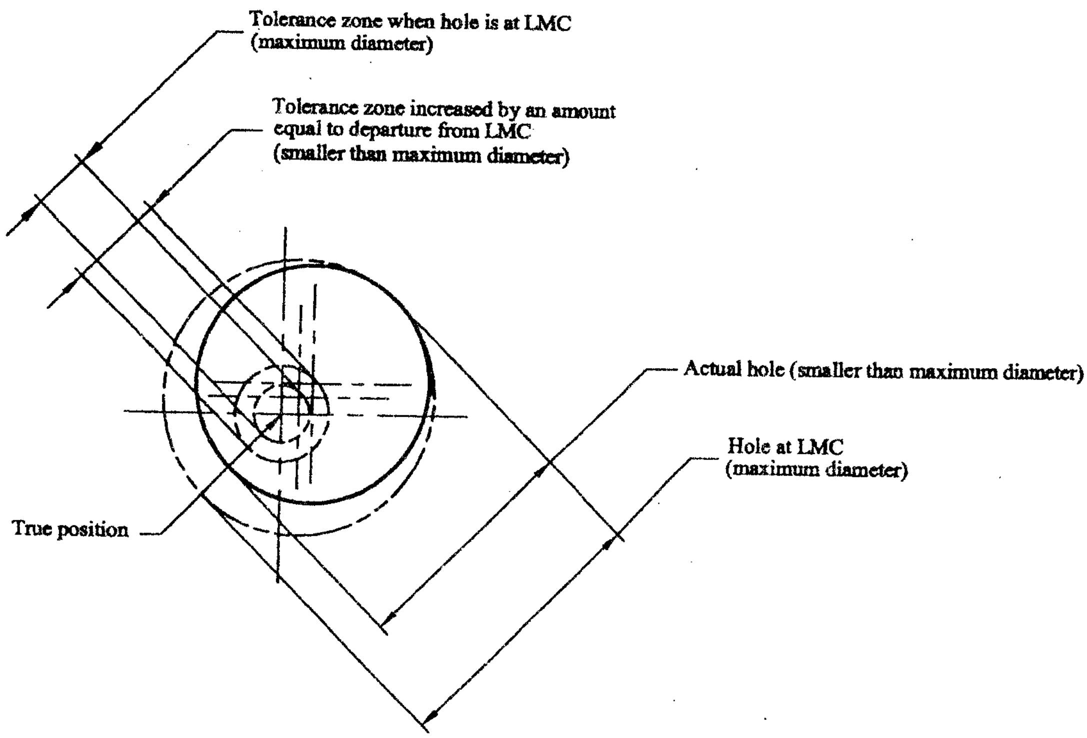
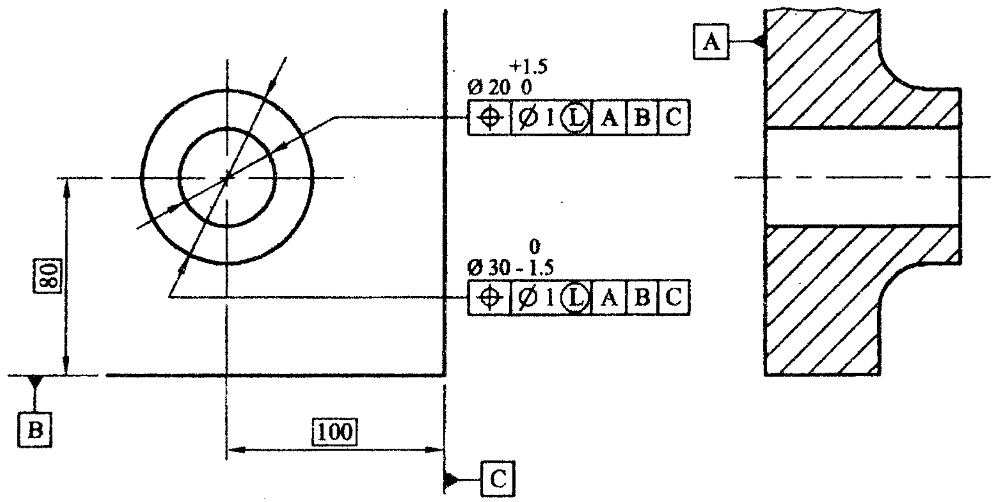


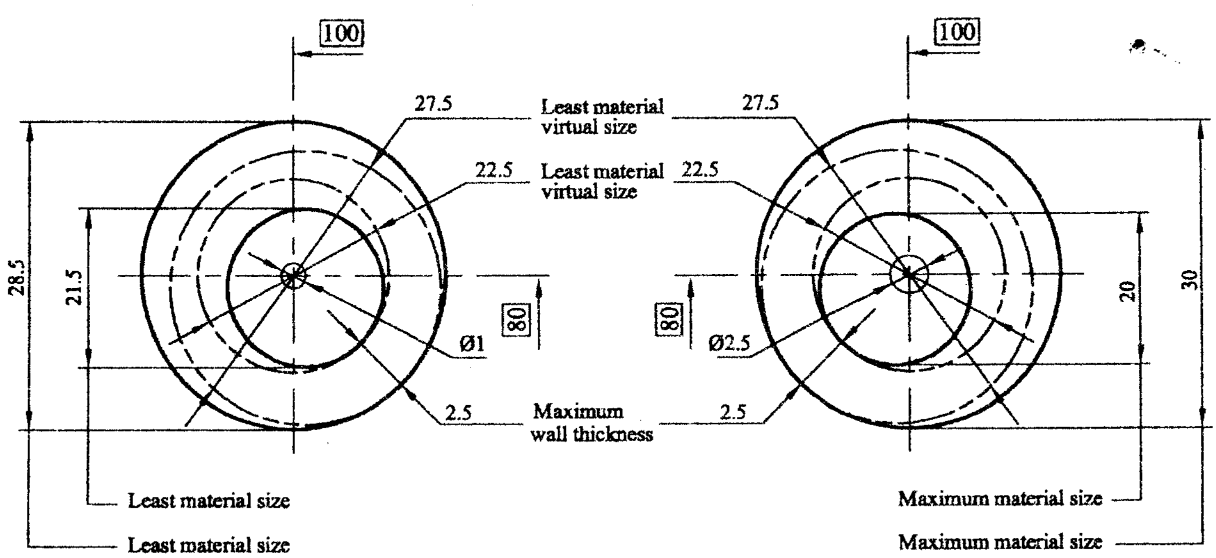
FIGURE 75 - Least material requirement

APPENDIX B
(Informative)

Examples of indication on the drawing and interpretation

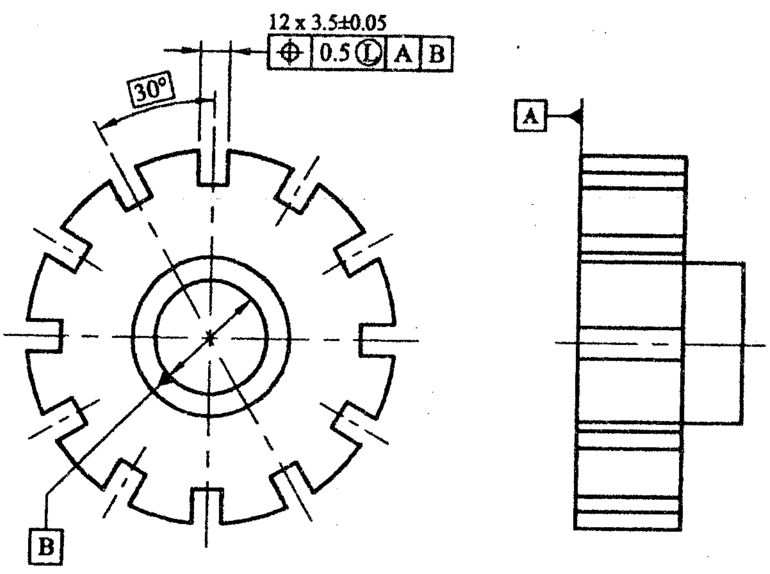


(a) Indication on the drawing

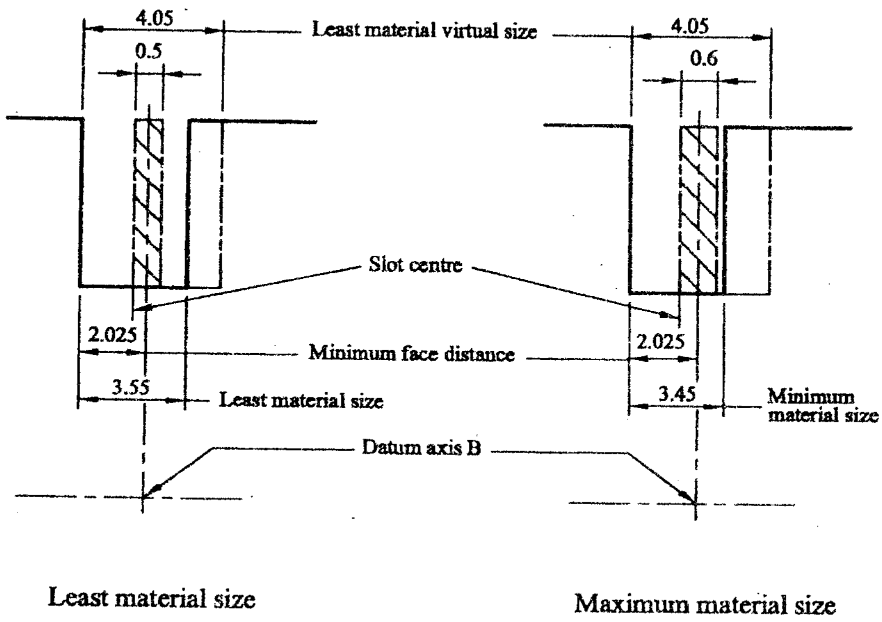


(b) Interpretation

FIGURE 76 - Least material requirement, minimum wall thickness

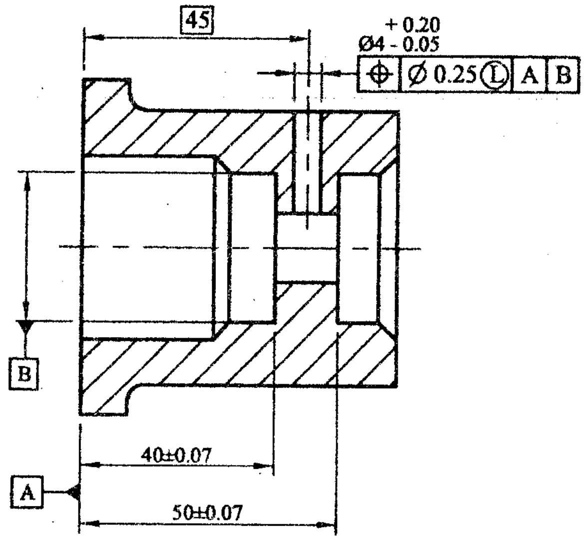


(a) Indication on the drawing

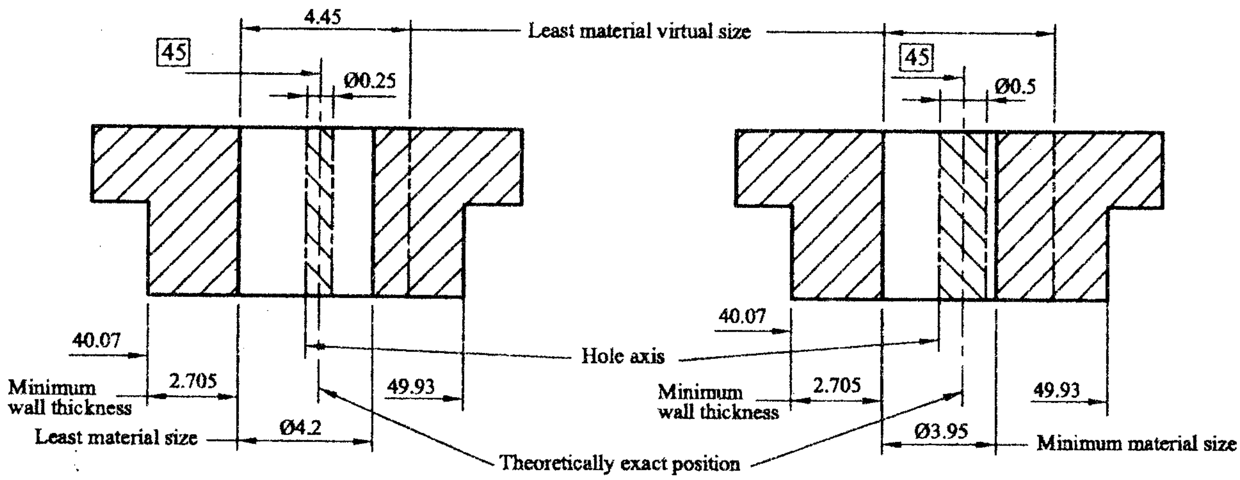


(b) Interpretation

FIGURE 77 - Least material requirement, maximum face distance



(a) Indication on the drawing

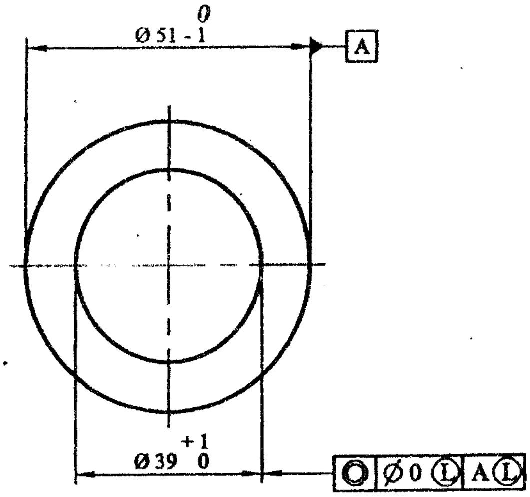


Least material size

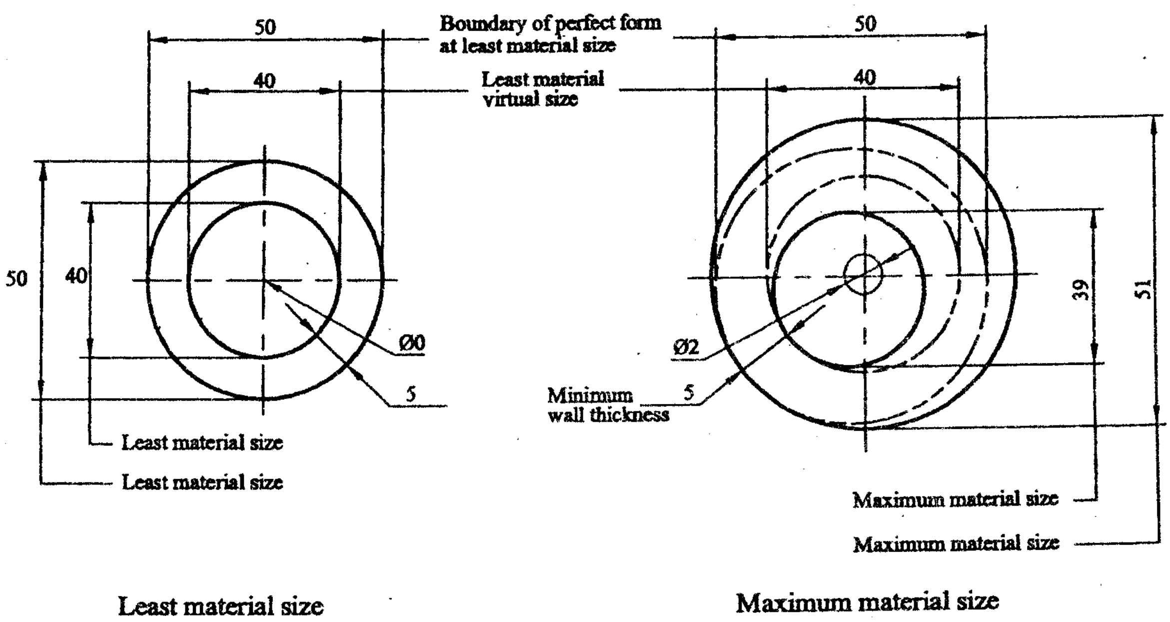
Maximum material size

(b) Interpretation

FIGURE 78 - Least material requirement, minimum wall thickness



(a) Indication on the drawing



(b) Interpretation

FIGURE 79 - Least material requirement, minimum wall thickness with perfect form at least material conditions (LMC)

Blank

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