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System of cone tolerances for conical workpieces from C = 1:3 to 1:500 and lengths from 6 to 630 mm

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 1947 was drawn up by Technical Committee ISO/TC 3, *Limits and fits,* and circulated to the Member Bodies in April 1970.

It has been approved by the Member Bodies of the following countries :

Austria	Greece	South Africa, Rep. of
Belgium	Hungary	Spain
Brazil	India	Sweden
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Germany	Portugal	

The Member Bodies of the following countries expressed disapproval of the document on technical grounds :

Australia
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System of cone tolerances for conical workpieces from $C = 1:3$ to $1:500$ and lengths from 6 to 630 mm

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies a cone tolerance system which applies to rigid conical workpieces for which the length of the generator can be considered as practically equal to the basic cone length; this applies in the case of cones having a rate of taper $C = 1:3$ to $1:500$.[1]

The appropriate tolerances of this International Standard can also be used for prismatic workpieces, for example wedges.

For the system of cone fits, see ISO . . . .[2]

For dimensioning and tolerancing cones on drawings, see ISO 3040, *Technical drawings — Dimensions and tolerancing cones.*[3]

For general information on tolerances of form and of position, see ISO/R 1101, *Tolerances of form and of position — Part I : Generalities, symbols, indications on drawings.*

For cone tolerances for rolling bearings, see ISO/R 492, *Rolling bearings — Radial bearings — Tolerances.*

The verification of cones will be the subject of a future document.

2 BASIS OF THE SYSTEM

2.1 Types of cone tolerance

The following four types of tolerance provide the basis of the cone tolerance system :

a) cone diameter tolerance T_D, valid for all cone diameters within the cone length L;

b) cone angle tolerance AT, given in angular or linear dimensions (AT_α or AT_D);

c) cone form tolerance T_F (tolerances for the straightness of the generator and for the roundness of the section);

d) cone section diameter tolerance T_{DS}, given for the cone diameter in a defined section. It is valid for the cone diameter of this section only.

2.2 Cone diameter tolerance, cone angle tolerance and cone form tolerance

Normal cases will be handled by application of the cone diameter tolerance T_D only. It includes the two tolerances of the types b) and c). This means that the deviations of these two types may, in principle, utilize the whole tolerance space given by the cone diameter tolerance T_D.

In case of stronger requirements, the cone angle tolerance and the cone form tolerance may be reduced within the cone diameter tolerance T_D by means of supplementary instructions. In this case likewise, no point on the conical surface is permitted to lie outside the limit cones given by T_D.

In practice, all types of tolerance generally exist at the same time and, as far as normal cases are concerned, each tolerance may occupy a part of the cone diameter tolerance T_D only in such a way that no point on the conical surface lies outside the tolerance space. In other words, no point on the conical surface is permitted to lie outside the limit cones.

2.3 Cone section diameter tolerance

If for functional reasons the cone diameter tolerance is required in a defined section, then the cone diameter tolerance T_{DS} (tolerance type d)) must be indicated. In this case, it is also necessary to indicate the cone angle tolerance.

If general tolerances for the cone angle are specified, for example in an international document, and if it is referred to this tolerance, then it is not necessary to indicate special cone angle tolerances.

3 DEFINITIONS

3.1 DEFINITIONS RELATING TO CONES

3.1.1 cone : A conical surface or a conical workpiece (see Figure 1), defined by its geometrical dimensions.

In the absence of any indication concerning the geometrical form, "cone" is understood to mean a straight circular cone or truncated cone.

1) For cones of 1 : 3 up to 1 : 500, the length of the generator and the cone length may be regarded as equal, since these lengths give differences in cone angle tolerances of less than 2 %.

2) In preparation.

3) At present at the stage of draft.

3.1.2 conical surface : A surface of revolution which is formed by rotating a straight line (generator) around an axis with the straight line intersecting this axis at the apex (see Figure 1).

The parts of this infinite conical surface are also known as conical surfaces or cones. Similarly, "cone" is also the abbreviated designation of a truncated cone.

3.1.3 conical workpiece : A workpiece or portion of a workpiece the main part of which is a conical surface (see Figures 2 and 3).

3.1.4 external cone : A cone which limits the outside form of a conical feature of a workpiece (see Figures 2 and 6).

3.1.5 internal cone : A cone which limits the inside form of a conical feature of a workpiece (see Figures 3 and 6).

3.1.6 basic cone : The geometrically ideal conical surface which is given by its geometrical dimensions. These are either

a) a basic cone diameter, the basic cone length and the basic rate of taper or the basic cone angle, or

b) two basic cone diameters and the basic cone length (see Figure 4).

3.1.7 actual cone : That cone the conical surface of which has been found by measurement (see Figure 5).

3.1.8 limit cones : The geometrically ideal coaxial surfaces, having the same basic cone angle, which result from the basic cone and the cone diameter tolerances. The difference between the largest and the smallest cone diameters is the same in all sections normal to the cone axis (see Figure 8).

The surfaces of the limit cones may be made to coincide by axial displacement.

3.1.9 generator : The line of intersection of the conical surface with a section in the axial plane (see Figures 1 and 6).

3.2 DEFINITIONS RELATING TO SIZES ON CONES

3.2.1 cone diameter : The distance between two parallel lines tangent to the intersection of the circular conical surface with a plane normal to the cone axis.

3.2.2 basic cone diameters are as follows : (see Figure 4)

a) the largest cone diameter D, or

b) the smallest cone diameter d, or

c) the cone diameter d_x at a place determined by its position in the axial direction.

3.2.3 actual cone diameter d_a : The distance between two parallel tangents to the intersection line of the surface of the actual cone with a defined plane normal to the cone axis (see Figure 5).

3.2.4 limit cone diameters : The diameters of the limit cones in each section in a plane normal to the axis (see Figure 8).

3.2.5 basic cone length L : The distance in the axial direction between two limiting ends of a cone (see Figures 4 and 6).

3.2.6 basic cone angle α : The angle formed by the two generators of the basic cone in a section in the axial plane (see Figure 7).

3.2.7 limit cone angles : The largest and the smallest cone angles resulting from the basic cone angle α and the position and magnitude of the cone angle tolerance (see Figure 10).

3.2.8 cone generating angle $\alpha/2$: The angle contained between a generator and the cone axis (see Figure 7).

The generating angle is equal to half the basic cone angle α.

3.2.9 rate of taper C : The ratio of the difference between the cone diameters D and d to the cone length L.

$$C = \frac{D-d}{L} = 2 \tan \frac{\alpha}{2}$$

The rate of taper is often indicated by the expressions 1 : x or 1/x and "Cone 1 : x" for short. For example, C = 1 : 20 means that a diameter difference $D-d$ of 1 mm occurs an axial distance L of 20 mm between the cone diameters D and d.

3.3 DEFINITIONS RELATING TO CONE TOLERANCES

3.3.1 cone tolerance system : A system containing the cone diameter tolerances, the cone angle tolerances and the tolerances on the cone form of the generator and the circumferential line of the section normal to the cone axis.

3.3.2 cone diameter tolerance T_D : The difference between the largest and smallest permissible cone diameters in *any* section, i.e. between the limit cones (see Figure 8).

3.3.3 cone angle tolerance AT[1] : The difference between the largest and smallest permissible cone angles (see Figures 10 and 15).

3.3.4 cone form tolerances T_F :

3.3.4.1 tolerance on the straightness of the generator : The distance between two parallel, straight lines between which the actual generator must lie (see Figure 8).

1) AT = angle tolerance.

The actual value for the error on straightness is taken as the distance between two parallel straight lines touching the actual generator, and so placed that the distance between them is a minimum.

3.3.4.2 tolerance on the roundness of the section : The distance between two coplanar concentric circles in a section normal to the axis between which the actual cone section must be situated (see Figure 9).

The actual value for the error on roundness is taken as the distance between two coplanar concentric circles which touch the actual line of any section normal to the axis.

3.3.5 cone section diameter tolerance T_{DS} : The difference between the largest and smallest permissible cone diameters in a *defined* section (see Figure 17).

3.4 DEFINITIONS RELATING TO ACTUAL CONE ANGLES

3.4.1 actual cone angle : In any axial plane section, the angle between the two pairs of parallel straight lines that enclose the form errors of the two generators in such a way that the maximum distance between them is the least possible value (see Figure 11).

For a given cone, there is not only one actual cone angle; for cones having deviations of roundness, the actual cone angle will be different in different axial planes (see α_1 and α_2 in Figure 11).

3.4.2 average actual cone angle : The arithmetical average value of the actual cone angle measured in accordance with 3.4.1 in several equally distributed axial plane sections.

Amongst the axial planes chosen, one at least shall cover the greatest deviation of roundness from the circle line of the cone diameter.

3.5 DEFINITION RELATING TO CONE TOLERANCE SPACE

3.5.1 cone tolerance space : For the conical surface, the space between the two limit cones.

Cone tolerance space includes all the tolerances referred to in 3.3. It may be represented by tolerance zones in two plane sections (see Figures 8 and 9).

3.6 DEFINITIONS RELATING TO CONE TOLERANCE ZONES

3.6.1 cone diameter tolerance zone : In a graphic representation, that zone, lying in the plane section of the cone axis, which is limited by the limit cones.

The total tolerances zone is represented in Figures 8 and 9 by the hatched portions which also indicate the cone tolerance space. It includes the tolerances for the cone diameter, the cone angle, the roundness and the straightness which can occupy the whole cone tolerance zone. In general, each of these particular deviations occupies a part of the cone diameter tolerance zone only.

3.6.2 tolerance zone for the cone angle : A fan-shaped zone within the limit cone angles.

The inclination of the limit cones can be indicated by plus, minus or plus/minus for the cone angle tolerances (see Figure 12). For the indication of plus/minus, the values can be different.

3.6.3 tolerance zone for the straightness of the generator : In a graphic representation, that zone (band), situated in any axial plane section and disposed on each side of the cone axis, which is determined by the form tolerance of the generators (see Figure 8).

As this zone is smaller than that referred to in 3.6.1, it only applies if the tolerance on the straightness of the generator is reduced with respect to the cone diameter tolerance zone. The actual generator has to be situated anywhere within a tolerance zone given by the tolerance for the straightness.

3.6.4 tolerance zone for the roundness of the section : In a graphic representation, the zone lying in a section normal to the cone axis and formed by concentric circles (see Figure 9).

As this zone is narrower than that referred to in 3.6.1, it only applies if the tolerance for the roundness of the section is reduced with respect to the cone diameter tolerance zone. The contour has to be situated anywhere within a tolerance zone given by the tolerance for the roundness of the section.

3.6.5 cone section diameter tolerance zone : The tolerance zone for the cone diameter in a defined section.

It appears in that case if the cone diameter tolerance is indicated for a fixed diameter only.

4 CONE DIAMETER TOLERANCE T_D

In general, the choice of the cone diameter tolerance T_D is based on the large cone diameter D. It is selected from the ISO standard IT tolerances and applies over the whole of the cone length L.

If it is not required to indicate smaller tolerances of angle and form, a cone diameter tolerance T_D, given on the drawing, applies also to the angle and form deviations. It should be borne in mind, however, that in this case all workpieces that conform to Figures 14 and 15 must be accepted.

The symbols of the ISO tolerances system shall be used to indicate the cone diameter tolerances referred to the corresponding cone diameter. If the conical surface of the conical workpiece concerned is not intended for a cone fit, the tolerance positions J_S and j_s should be chosen for preference, for example, 40 j_s10.

5 CONE ANGLE TOLERANCE AT

5.1 Cone angle tolerance resulting from the cone diameter tolerance T_D

The actual cone angle lies within the cone diameter tolerance zone in case of absence of any special indication of cone angle tolerances. The cone angles α_{max} and α_{min} (see Figure 15) are thus the limit cone angles resulting from the cone diameter tolerance T_D. Consequently, in this case, the actual cone angle is permitted to be disposed with respect to the basic cone angle α from $+\Delta\alpha$ to $-\Delta\alpha$ (for values of $\Delta\alpha$, see the table in the annex).

5.2 Fixed cone angle tolerance

If the cone angle tolerance has to be smaller than that given by the cone diameter tolerance, it is necessary to establish the cone angle limits. For the cone angle tolerances, the deviations must be indicated by plus, minus or plus/minus, for example, $+AT$, $-AT$, $\pm AT/2$.

For the indication of plus/minus, the values can be different.

6 CONE FORM TOLERANCES T_F

Cone form tolerances comprise the tolerances on

a) the straightness of the generator (see Figure 8),

b) the roundness of the cone section (see Figure 9).

Cone form tolerances shall be especially indicated (in micrometres) if they must be smaller than half of the cone diameter tolerance.

7 CONE SECTION DIAMETER TOLERANCE T_{DS}

If the cone diameter tolerance should be reduced locally and should be given for a defined section only, for functional or manufacturing reasons, the cone diameter tolerance must be indicated for this section only.

8 TABLE OF CONE ANGLE TOLERANCES

Structure of the table

As the cone angle tolerances AT have different functions, they are stepped in grades represented by numbers : for example AT 5. They are expressed in microradians (μrad)[1] for AT_α or in micrometres (μm) for AT_D, calculated from the constant AT_α value within a range of cone lengths. AT_D is valid normal to the axis[2] in the form of a diameter difference. It must be smaller with respect to the cone diameter tolerance T_D. Taking account of the units, (micrometres, microradians), the following relationship exists (see also Figure 16) :

$$AT_D = AT_\alpha \times L$$

The grade numbers for IT (diameter) and AT (angle) tolerances are chosen in such a way that the same numbers correspond to approximately the same difficulties of manufacture. No direct relation is given, however, because the IT values are stepped in accordance with the diameter of cylindrical workpieces, whereas the AT values are stepped in accordance with the cone length L.

The ratio for the cone angle tolerances from one AT grade to the next higher grade is 1,6. It is necessary to relate the cone angle tolerance AT to the cone length L, because the longer the length of cone, the better the angle may be met. The cone lengths L from 6 to 630 mm are divided into ten ranges with a stepped ratio of 1,6.

The AT_α values decrease from one range of length to the next higher range by a step of 0,8, which corresponds to the experimental relationship

$$AT_\alpha \sim \frac{1}{\sqrt{L}}$$

As the AT_α values are held constant in a cone length range, it is the corresponding AT_D values that vary. They are given for the limits of the ranges of lengths and increase from one length range to the next with a ratio of 1,25.

Figure 16 shows the largest and smallest values for AT_D resulting from the largest (L_{max}) and smallest (L_{min}) basic lengths of a length range at a constant AT_α value.

No relationship is provided for between the cone angle tolerance and the cone diameter because of lack of experience. The introduction of such a relationship will be made in future if sufficient experience is available. In the case of conical workpieces with large cone diameter, it is left to the user to select a higher AT grade than that used for conical workpieces of small diameter.

If finer or coarser angle tolerances are necessary, they shall be calculated by division or multiplication by 1,6 from the AT_1 and AT_{12} values respectively. The finer AT grades shall be designated AT 0, AT 01.

1) 1 μrad = an angle producing an arc of length 1 μm at a radial distance of 1 m.
5 μrad ≈ 1 " (1 second); 300 μrad ≈ 1' (1 minute).

2) The measurement normal to the cone axis is regarded as equivalent to the theoretical correct measurement normal to the generator as the difference of the measured AT_D values is only 2 % even for a cone 1 : 3.

Range of cone length L mm		Cone angle tolerance grades AT 1			AT 2			AT 3		
		AT_α		AT_D	AT_α		AT_D	AT_α		AT_D
over	up to	µrad	seconds	µm	µrad	seconds	µm	µrad	seconds	µm
6	10	50	10″	0,3...0,5	80	16″	0,5...0,8	125	26″	0,8.....1,3
10	16	40	8″	0,4...0,6	63	13″	0,6...1	100	21″	1........1,6
16	25	31,5	6″	0,5...0,8	50	10″	0,8...1,3	80	16″	1,3.....2
25	40	25	5″	0,6...1	40	8″	1......1,6	63	13″	1,6.....2,5
40	63	20	4″	0,8...1,3	31,5	6″	1,3...2	50	10″	2........3,2
63	100	16	3″	1......1,6	25	5″	1,6...2,5	40	8″	2,5.....4
100	160	12,5	2,5″	1,3...2	20	4″	2......3,2	31,5	6″	3,2.....5
160	250	10	2″	1,6...2,5	16	3″	2,5...4	25	5″	4........6,3
250	400	8	1,5″	2......3,2	12,5	2,5″	3,2...5	20	4″	5........8
400	630	6,3	1″	2,5...4	10	2″	4......6,3	16	3″	6,3.....10

Range of cone length L mm		Cone angle tolerance grades AT 4			AT 5			AT 6		
		AT_α		AT_D	AT_α		AT_D	AT_α		AT_D
over	up to	µrad	seconds	µm	µrad	minutes seconds	µm	µrad	minutes seconds	µm
6	10	200	41″	1,3.....2	315	1′05″	2......3,2	500	1′43″	3,2.....5
10	16	160	33″	1,6.....2,5	250	52″	2,5.....4	400	1′22″	4........6,3
16	25	125	26″	2......3,2	200	41″	3,2.....5	315	1′0,5″	5........8
25	40	100	21″	2,5.....4	160	33″	4........6,3	250	52″	6,3...10
40	63	80	16″	3,2.....5	125	26″	5........8	200	41″	8......12,5
63	100	63	13″	4........6,3	100	21″	6,3...10	160	33″	10......16
100	160	50	10″	5........8	80	16″	8......12,5	125	26″	12,5...20
160	250	40	8″	6,3...10	63	13″	10......16	100	21″	16......25
250	400	31,5	6″	8......12,5	50	10″	12,5...20	80	16″	20......32
400	630	25	5″	10.....16	40	8″	16......25	63	13″	25......40

Range of cone length L mm		Cone angle tolerance grades AT 7			AT 8			AT 9		
		AT_α		AT_D	AT_α		AT_D	AT_α		AT_D
over	up to	µrad	minutes seconds	µm	µrad	minutes seconds	µm	µrad	minutes seconds	µm
6	10	800	2′45″	5........8	1 250	4′18″	8.....12,5	2 000	6′52″	12,5.....20
10	16	630	2′10″	6,3...10	1 000	3′26″	10......16	1 600	5′30″	16........25
16	25	500	1′43″	8......12,5	800	2′45″	12,5...20	1 250	4′18″	20.........32
25	40	400	1′22″	10......16	630	2′10″	16......25	1 000	3′26″	25........40
40	63	315	1′05″	12,5...20	500	1′43″	20......32	800	2′45″	32........50
63	100	250	52″	16......25	400	1′22″	25......40	630	2′10″	40........63
100	160	200	41″	20......32	315	1′05″	32......50	500	1′43″	50........80
160	250	160	33″	25......40	250	25″	40......63	400	1′22″	63......100
250	400	125	26″	32......50	200	41″	50......80	315	1′05″	80......125
400	630	100	21″	40......63	160	33″	63....100	250	52″	100....160