
Specification for

Involute splines: metric module, side fit

Part 1. Dimensions and tolerances

[ISO title: Straight cylindrical involute splines — Metric module, side fit —
Generalities, dimensions and inspection]

Spécification pour les cannelures à flancs en développante: module métrique, à centrage sur flancs
Partie 1. Dimensions et tolérances

Spezifikation für Evolventenkeilnuten: metrischer Modul, Seitenpassung
Teil 1. Abmessungen und Toleranzen

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metric module, side fit
Part 1. Dimensions and tolerances

Correction

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National foreword

Insert the following paragraphs at the end of the national foreword.

Textual errors. The textual errors given below have been discovered. They have been marked in the text and have been reported to the International Organization for Standardization (ISO) in a proposal to amend the text of the international standard.

The ten columns of data below the headings of table 28 and table 29 have been transposed. Thus, the data under table 28 relates to the headings of table 29 and the data under table 29 relates to the headings of table 28.'

AMD 4602
June 1984

Table 28. External spline

Insert an asterisk at the end of the title of the table.

At the foot of the table insert '*See national foreword.'

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Table 29. Internal spline

Insert an asterisk at the end of the title of the table.

At the foot of the table insert '*See national foreword.'

1

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National foreword

This Part of this British Standard has been prepared under the direction of the Mechanical Engineering Standards Committee. It is identical with sections one and two of ISO 4156 'Straight cylindrical involute splines — Metric module, side fit — Generalities, dimensions and inspection' which were published in 1981 by the International Organization for Standardization (ISO). 'Section three: Inspection' of the international standard is in course of preparation and will form an addendum to ISO 4156. Part 2 of this British Standard, dealing with gauging and inspection, is expected to be identical with the addendum to ISO 4156.

NOTE. It should be noted that clause 1 'Scope and field of application' of this Part refers to all three sections of ISO 4156, and hence includes Part 2 of the British Standard.

Terminology and conventions. The text of the international standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is especially drawn to the following.

The comma has been used as a decimal marker, except in tables 15 to 116 inclusive. In British Standards it is current practice to use a full point on the baseline as the decimal marker.

Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'British Standard'.

Cross-reference

International standard	Corresponding British Standard
ISO R/286-1962	BS 4500 Specification for ISO limits and fits Part 1 : 1969 General, tolerances and deviations. (Technically equivalent)

A related British Standard to ISO 1328-1975, which is referred to in 8.4 and 8.5 for information purposes, is BS 436 'Specification for spur and helical gears' Part 2 : 1970 'Basic rack form, modules and accuracy (1 to 50 metric module)'.

British Standard Specification for

Involute splines: metric module, side fit

Part 1. Dimensions and tolerances

Section one: Generalities

1 Scope and field of application

This International Standard provides data and guidance for the design, manufacture and inspection of straight (non-helical) cylindrical involute splines with side fit. It establishes a specification based on the module within the range 0,25 to 10 inclusive, relating to nominal pressure angles of 30° , $37,5^\circ$ and 45° . (For electronic data processing purposes, the form of expression " $37,5^\circ$ " has been adopted instead of $37^\circ 30'$.)

Limiting dimensions, tolerances, manufacturing errors and their effects on the fit between connecting co-axial spline elements are defined and tabulated. Linear dimensions are expressed in millimetres and angular dimensions in degrees.

2 Terms and definitions relating to splines

2.1 spline joint : Connecting, co-axial elements that transmit torque through the simultaneous engagement of equally spaced teeth situated around the periphery of a cylindrical external member with similar spaced mating spaces situated around the inner surface of the related cylindrical internal member.

2.2 involute spline : One member of spline joint having teeth or spaces that have involute flank profiles.

2.3 internal spline : A spline formed on the inner surface of a cylinder.

2.4 external spline : A spline formed on the outer surface of a cylinder.

2.5 fillet : The concave surface of the tooth or space connecting the involute flank and the root circle. This curved surface as generated varies and cannot be properly specified by a radius of any given value.

2.6 fillet root spline : A spline having a tooth or space profile in which the opposing involute flanks are connected to the root circle (D_{ei} or D_{ie} diameter) by a single fillet.

2.7 flat root spline : A spline having a tooth or space profile in which each of the opposing involute flanks are connected to the root circle (D_{ei} or D_{ie} diameter) by a fillet.

2.8 module, m : The ratio of the circular pitch, expressed in millimetres, to the number π (or the ratio of the pitch diameter, expressed in millimetres, to the number of teeth).

2.9 pitch circle : The reference circle from which all normal spline dimensions are derived, and the circle on which the specified pressure angle has its nominal value.

2.10 pitch diameter, D : The diameter of the pitch circle, in millimetres, equal to the number of teeth multiplied by the module.

2.11 pitch point : The intersection of the spline tooth profile with the pitch circle.

2.12 circular pitch, p : A length of arc of the pitch circle between two consecutive pitch points of left- (or right-) hand flanks, which has a normal value of the number π multiplied by the module.

2.13 pressure angle, α : The acute angle between a radial line passing through any point on a tooth flank and the tangent plane to the flank at that point.

2.14 standard pressure angle, α_D : The pressure angle at the specified pitch point.

2.15 base circle : The circle from which involute spline tooth profiles are generated.

2.16 base diameter, D_b : The diameter of the base circle.

2.17 base pitch, p_b : The arc length of the base circle between two consecutive corresponding flanks.

2.18 major circle : The circle formed by the outermost surface of the spline. It is the outside circle (tooth tip circle) of the external spline or the root circle of the internal spline.

2.19 major diameter, D_{ee} , D_{ei} : The diameter of the major circle.

2.20 minor circle : The circle formed by the innermost surface of the spline. It is the root circle of the external spline or the inside circle (tooth tip circle) of the internal spline.

2.21 minor diameter, D_{ie} , D_{ii} : The diameter of the minor circle.

2.22 form circle : The circle which establishes the deepest points of involute form control of the tooth profile. This circle along with the tooth tip circle (or start of chamfer circle) determines the limits of tooth profile requiring control. It is located near and below the major circle on the internal spline and near and above the minor circle on the external spline.

2.23 form diameter, D_{Fe} , D_{Fi} : The diameter of the form circle.

2.24 depth of engagement : The radial distance from the minor circle of the internal spline to the major circle of the external spline, minus corner clearance and/or chamfer depth.

2.25 basic (circular) space width or tooth thickness at the pitch diameter, E or S : For 30°, 37,5° and 45° pressure angle splines, half the circular pitch.

2.26 actual space width : The practically measured circular space width, on the pitch circle, of any single space width within the limit values E_{max} and E_{min} .

2.27 effective space width, E_v : For an internal spline, equal to the circular tooth thickness on the pitch circle of an imaginary perfect external spline which would fit the internal spline without looseness or interference, considering engagement of the entire axial length of the splined assembly. The minimum effective space width ($E_{v min}$, always equal to E) of the internal spline is always basic, as shown in table 1. Fit variations may be obtained by adjusting the tooth thickness of the external spline.

2.28 actual tooth thickness : The practically measured circular tooth thickness, on the pitch circle, of any single tooth within the limit values S_{max} and S_{min} .

2.29 effective tooth thickness, S_v : For an external spline, equal to the circular space width on the pitch circle of an imaginary perfect internal spline which would fit the external spline without looseness or interference, considering engagement of the entire axial length of the splined assembly. Fit variations are obtained by adjusting this value S_v .

2.30 effective clearance, c_v (looseness or interference) : The effective space width of the internal spline minus the effective tooth thickness of the mating external spline.

2.31 theoretical clearance, c (looseness or interference) : The actual space width of an internal spline minus the actual tooth thickness of the mating external spline. It does not define the fit between mating members, because of the effect of variations.

2.32 form clearance, c_F : The radial depth of involute profile beyond the depth of engagement with the mating part. It allows eccentricity of the minor circle (internal), of the major circle (external) and of their respective pitch circles.

2.33 total index variation : Amount of absolute values of the two greatest actual (or practically measured) positive and negative variations from the theoretical spacing.

2.34 total profile variation : Amount of absolute values of the two greatest positive and negative variations, from the theoretical tooth profiles, measured normal to flanks.

2.35 total lead variation : Amount of absolute values of the two greatest opposite direction variations, from the theoretical direction (parallel to the datum axis), also including parallelism and alignment variations (see figure 1).

NOTE — Straight (non-helical) splines have an infinite lead.

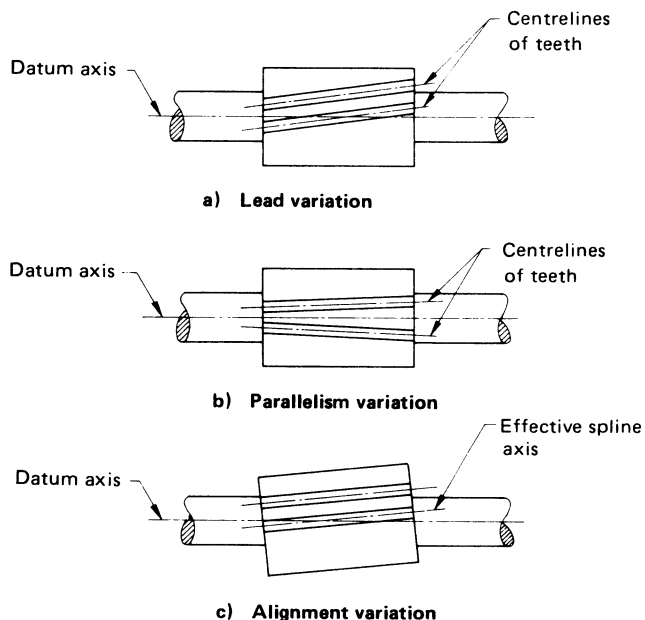


Figure 1 — Lead variations

2.36 parallelism variation : The variation of parallelism of a single spline tooth to any other single spline tooth (see figure 1).

2.37 alignment variation : The variation of the effective spline axis with respect to the reference axis (see figure 1).

2.38 out-of-roundness : The variation of the spline from a true circular configuration.

2.39 effective variation : The accumulated effect of the spline variations on the fit with the mating part.

2.40 variation allowance, λ : The permissible effective variation.

2.41 machining tolerance, T : The permissible variation in actual space width or actual tooth thickness.

2.42 total tolerance, $(T + \lambda)$: The machining tolerance plus the variation allowance. The total tolerance on an internal spline is the difference between the minimum effective space width and the maximum actual space width; on an external spline, it is the difference between the maximum effective tooth thickness and the minimum actual tooth thickness.

2.43 length of engagement, g_y : The axial length of contact between mating splines.

2.44 active spline length, g_w : The maximum axial spline length in contact (when working) with the mating spline. On sliding splines, the active length exceeds the length of engagement.

2.45 basic dimension : A numerical value to describe the theoretically exact size, shape or location of a feature. It is the basis from which permissible variations are established by tolerances.

2.46 auxiliary dimension : A dimension, without tolerance, given for information purposes only, for the determination of the useful production and control dimensions.

3 Symbols

3.1 General symbols

The general symbols used to designate the various spline terms and dimensions are given below (see figures 10, 11, 12, 13, 14 and 15).

NOTE — In electronic data processing (EDP), it is not always possible to present symbols in their theoretically correct form because of limitations of connected printing equipment. For this reason, some alternative symbols for EDP usage are given in brackets below (for example, the symbol D_b for base diameter may be printed as DB).

c_v = effective clearance (looseness or interference)

c_F = form clearance

D = pitch diameter

D_b [DB] = base diameter

d_{ci} = pin contact diameter, internal spline

d_{ce} = pin contact diameter, external spline

D_{Fe} [DFE] = form diameter, external spline

D_{Fi} [DFI] = form diameter, internal spline

D_{ii} [DII] = minor diameter, internal spline

D_{ee} [DEE] = major diameter, external spline

D_{ie} [DIE] = minor diameter, external spline

D_{ei} [DEI] = major diameter, internal spline

D_{Re} [DRE] = diameter of measuring pin for external spline

D_{Ri} [DRI] = diameter of measuring pin for internal spline

λ = variation allowance

$\text{inv } \alpha$ = involute α ($= \tan \alpha - \alpha$)

K_e [KE] = approximation factor for external spline

K_i [KI] = approximation factor for internal spline

g = spline length

g_w = active spline length

g_y = length of engagement

T = machining tolerance

M_{Re} [MRE] = measurement over two pins, external spline

M_{Ri} [MRI] = measurement between two pins, internal spline

W = measurement over k teeth, external spline

Z = number of teeth

m = module

p_b = base pitch

p = circular pitch

ρ_{Fe} = fillet radius of the basic rack, external spline

ρ_{Fi} = fillet radius of the basic rack, internal spline

E = basic space width, circular

$E_{\max}$ = actual maximum space width, circular

$E_{\min}$ = actual minimum space width, circular

E_v [EV] = effective space width, circular

S = basic tooth thickness, circular

$S_{\max}$ = actual maximum tooth thickness, circular

$S_{\min}$ = actual minimum tooth thickness, circular

S_v [SV] = effective tooth thickness, circular

α = pressure angle

α_D = standard pressure angle

α_{ci} = pressure angle at pin contact diameter, internal spline

α_{ce} = pressure angle at pin contact diameter, external spline

α_i = pressure angle at pin centre, internal spline

α_e = pressure angle at pin centre, external spline

α_{Fe} = pressure angle at form diameter, external spline

α_{Fi} = pressure angle at form diameter, internal spline

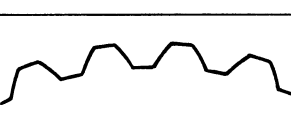
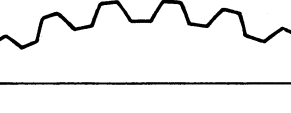
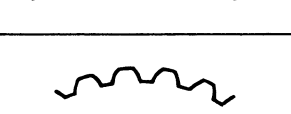
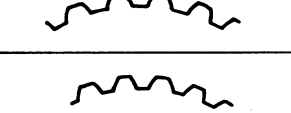
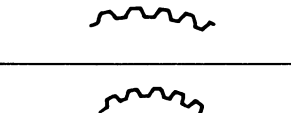
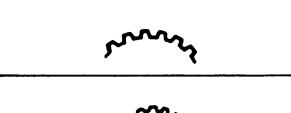
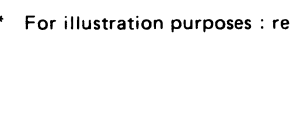
$k - j_s - h - f - e$ and d = fundamental deviation on the external spline = $c_{v \min}$

H = fundamental deviation on the internal spline

Tables 1 and 2 give the basic dimensions and fundamental formulae, a graphical presentation of which is given by figure 2.

Table 1 — Theoretical dimensions for splines

Dimensions in millimetres

Tooth $\alpha_D 30^\circ$ *	Module m	Circular pitch p	Basic space width or tooth thickness at pitch diameter E or S			Base pitch p_b		
			$\alpha_D 30^\circ$	$\alpha_D 37,5^\circ$	$\alpha_D 45^\circ$	$\alpha_D 30^\circ$	$\alpha_D 37,5^\circ$	$\alpha_D 45^\circ$
	10	31,416	15,708	15,708	—	27,207 0	24,923 9	—
	8	25,133	12,566	12,566	—	21,765 6	19,939 2	—
	6	18,850	9,425	9,425	—	16,324 2	14,954 4	—
	5	15,708	7,854	7,854	—	13,603 5	12,462 0	—
	4	12,566	6,283	6,283	—	10,882 8	9,969 6	—
	3	9,425	4,712	4,712	—	8,162 1	7,477 2	—
	2,5	7,854	3,927	3,927	3,927	6,801 7	6,231 0	5,553 6
	2	6,283	3,142	3,142	3,142	5,441 4	4,984 8	4,442 9
	1,75	5,498	2,749	2,749	2,749	4,761 2	4,361 7	3,887 5
	1,5	4,712	2,356	2,356	2,356	4,081 0	3,738 6	3,332 2
	1,25	3,927	1,963	1,963	1,963	3,400 9	3,115 5	2,776 8
	1	3,142	1,571	1,571	1,571	2,720 7	2,492 4	2,221 4
	0,75	2,356	1,178	1,178	1,178	2,040 5	1,869 3	1,666 1
	0,5	1,571	0,785	0,785	0,785	1,360 4	1,246 2	1,110 7
	0,25	0,785	—	—	0,393	—	—	0,555 4

* For illustration purposes : relative tooth sizes for various spline modules for pressure angle $\alpha_D = 30^\circ$.

Table 2 — Formulae for dimensions and tolerances for all fit classes

Term	Symbol	Formula
Pitch diameter	D	$m Z$
Base diameter	D_b	$m Z \cos \alpha_D$
Circular pitch	p	πm
Base pitch	p_b	$\pi m \cos \alpha_D$
Effective upper deviation, external	es_v	resulting from deviation allowance (fundamental) $k - j_s - h - f - e$ and d
Minimum diameter, internal		
30°, flat root	$D_{ei \min}$	$m(Z + 1,5)$
30°, fillet root	$D_{ei \min}$	$m(Z + 1,8)$
37,5°, fillet root	$D_{ei \min}$	$m(Z + 1,4)$
45°, fillet root	$D_{ei \min}$	$m(Z + 1,2)$
Maximum major diameter, internal	$D_{ei \max}$	$D_{ei \min} + (T + \lambda)/\tan \alpha_D$ (see note 1)
Minimum form diameter, internal		
30°, flat root and fillet root	$D_{Fi \min}$	$m(Z + 1) + 2 c_F$
37,5°, fillet root	$D_{Fi \min}$	$m(Z + 0,9) + 2 c_F$
45°, fillet root	$D_{Fi \min}$	$m(Z + 0,8) + 2 c_F$
Minimum diameter, internal	$D_{ii \min}$	$D_{Fe \max} + 2 c_F$ (see note 2)
Maximum minor diameter, internal		
$m \leq 0,75$	$D_{ii \max}$	$D_{ii \min} + \text{tol. H 10}$
$0,75 < m < 2$	$D_{ii \max}$	$D_{ii \min} + \text{tol. H 11}$
$m \geq 2$	$D_{ii \max}$	$D_{ii \min} + \text{tol. H 12}$
Basic space width and	E and	$0,5 \pi m$
Minimum effective space width	$E_{v \min}$	
Maximum actual space width		
class 4	$E_{\max}$	$E_{v \min} + (T + \lambda)$ (see note 3)
class 5	$E_{\max}$	$E_{v \min} + (T + \lambda)$ (see note 3)
class 6	$E_{\max}$	$E_{v \min} + (T + \lambda)$ (see note 3)
class 7	$E_{\max}$	$E_{v \min} + (T + \lambda)$ (see note 3)
Minimum actual space width	$E_{\min}$	$E_{v \min} + \lambda$ (see 8.2)
Maximum effective space width	$E_{v \max}$	$E_{\max} - \lambda$ (see 8.2)
Maximum major diameter, external		
30°, flat root and fillet root	$D_{ee \max}$	$m(Z + 1) + es_v/\tan \alpha_D$ (see note 4)
37,5°, fillet root	$D_{ee \max}$	$m(Z + 0,9) + es_v/\tan \alpha_D$ (see note 4)
45°, fillet root	$D_{ee \max}$	$m(Z + 0,8) + es_v/\tan \alpha_D$ (see note 4)
Minimum major diameter, external		
$m \leq 0,75$	$D_{ee \min}$	$D_{ee \max} - \text{tol. h 10}$
$0,75 < m < 2$	$D_{ee \min}$	$D_{ee \max} - \text{tol. h 11}$
$m \geq 2$	$D_{ee \min}$	$D_{ee \max} - \text{tol. h 12}$
Maximum form diameter, external	$D_{Fe \max}$	$2 \sqrt{(0,5 D_b)^2 + \left(0,5 D \sin \alpha_D - \frac{h_s - \frac{0,5 es_v}{\tan \alpha_D}}{\sin \alpha_D}\right)^2}$ (See note 6)
Maximum minor diameter, external		
30°, flat root	$D_{ie \max}$	$m(Z - 1,5) + es_v/\tan \alpha_D$
30°, fillet root	$D_{ie \max}$	$m(Z - 1,8) + es_v/\tan \alpha_D$
37,5°, fillet root	$D_{ie \max}$	$m(Z - 1,4) + es_v/\tan \alpha_D$
45°, fillet root	$D_{ie \max}$	$m(Z - 1,2) + es_v/\tan \alpha_D$

Table 2 — Formulae for dimensions and tolerances for all fit classes (*concluded*)

Term	Symbol	Formula
Minimum minor diameter, external	$D_{ie\ min}$	$D_{ie\ max} - (T + \lambda)/\tan \alpha_D$ (see note 1)
Basic tooth thickness	S	$0,5 \pi m$
Maximum effective tooth thickness	$S_{v\ max}$	$S + es_v$
Minimum actual tooth thickness		
class 4	S_{min}	$S_{v\ max} - (T + \lambda)$ (see note 3)
class 5	S_{min}	$S_{v\ max} - (T + \lambda)$ (see note 3)
class 6	S_{min}	$S_{v\ max} - (T + \lambda)$ (see note 3)
class 7	S_{min}	$S_{v\ max} - (T + \lambda)$ (see note 3)
Maximum actual tooth thickness	S_{max}	$S_{v\ max} - \lambda$
Minimum effective tooth thickness	$S_{v\ min}$	$S_{min} + \lambda$
Total tolerance, space width or tooth thickness	$(T + \lambda)$	(see clause 6)
Form clearance	c_F	$0,1 m$
Pin diameter, internal spline	D_{Ri}	see note 5
Pin diameter, external spline	D_{Re}	see note 5
Measurement between pins	M_{Ri}	see note 5
Measurement over pins	M_{Re}	see note 5
Change factor, internal	K_i	see section three, "Inspection"
Change factor, external	K_e	see section three, "Inspection"

NOTES

- 1 $(T + \lambda)$ for class 7 — see clause 6.
- 2 For all classes of fit, always take the $D_{Fe\ max}$ value corresponding to the H/h fit.
- 3 See clause 6 and section two — tables of dimensions.
- 4 Take a null upper deviation value for j_s and k fundamental deviations.
- 5 See section two : "Dimensions", and section three : "Inspection", concerning choice of pins.
- 6 For h_s see figures 3, 4, 5 and 6.



3.2 Subscripts

The following subscripts (see also the note in 3.1) are used as part of the above general symbols to designate relative conditions or locations :

$i[I]$ = minor or internal (in this last case, in the last position)

$e[E]$ = major or external (in this last case, in the last position)

$b[B]$ = at base

c = at contact point

$f[F]$ = pertaining to form diameter

$v[V]$ = effective

w = active

$R[R]$ = pertaining to gauges

γ = of engagement

D = standard

4 Pressure angle (standard)

Standard pressure angles included in this International Standard for involute splines are 30°, 37,5° and 45°.

5 Type of fit

This International Standard deals with only one type of fit, the side fit, for 30°, 37,5° and 45° pressure angle splines. Formulae for the dimensions and tolerances for these splines are shown in table 2.

5.1 Side fit

In this fit, the mating members contact on the sides of the teeth only. Major and minor diameters are clearance dimensions. The tooth sides act as drivers and centralize mating splines.

5.2 Spline fit classes

This International Standard provides the side fit in six spline fit

classes as follows :

Spline fit class	Effective interference
H/k	$c_{v \max} = (T + \lambda)$
H/j _s	$c_{v \max} = \text{deviation allowance } j_s = \left(\frac{T + \lambda}{2} \right)$
	Effective looseness
H/h	$c_{v \min} = \text{deviation allowance } h = \text{zero}$
H/f	$c_{v \min} = \text{deviation allowance } f$
H/e	$c_{v \min} = \text{deviation allowance } e$
H/d	$c_{v \min} = \text{deviation allowance } d$

The deviation allowances (fundamental) $k - j_s - h - f - e$ and d are the standard deviations selected from ISO/R 286 /ISO System of limits and fits — Part 1 : General, tolerances and deviations, which are applied to the external spline. A prescribed maximum effective interference or minimum effective looseness is obtained, allowing the fitting by adjusting from the zero line the maximum effective and minimum actual limit values of tooth thickness by the amount of the deviation allowance (see 8.7.2). The spline dimensions in the spline tables of this International Standard are given for spline fit class H/h, $c_{v \min} = \text{zero}$.

6 Space width and tooth thickness, total tolerance ($T + \lambda$)

Tolerance classes

This International Standard includes four classes of total tolerance ($T + \lambda$) on space width and tooth thickness selected from a combination of tolerance units (i) in ISO/R 286. The tolerance classes are indicated below, with corresponding combination of tolerance units (i). For the calculation of T and λ , see clause 8. The values of λ are given in tables 3 to 6 of clause 8.

Spline tolerance class	Tolerance unit (i)
4	$= (10 i^* + 40 i^{**})$
5	$= (16 i^* + 64 i^{**})$
6	$= (25 i^* + 100 i^{**})$
7	$= (40 i^* + 160 i^{**})$

* Tolerance based on pitch diameter

$$i = 0,45 \sqrt[3]{D} + 0,001 D \quad \text{for } D < 500 \text{ mm}$$

$$i = 0,004 D + 2,1 \quad \text{for } D > 500 \text{ mm}$$

** Tolerance based on space width or tooth thickness

$$i = 0,45 \sqrt[3]{E \text{ (or } S)} + 0,001 E \text{ (or } S)$$

where

D is the pitch diameter in millimetres;

E is the basic space width in millimetres;

S is the basic tooth thickness in millimetres.

the resultant ($T + \lambda$) in micrometres. For ($T + \lambda$) in millimetres, multiply the result by 0,001.

For the calculation of tolerance units (i), only the above indicated formulae (notes *, **) are to be taken into consideration.



Documents

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It should be noted that total values ($T + \lambda$) may **always** be subtracted from the limit values of space width and tooth thickness given in section 2 and are usable even if the chosen fit class is other than H/h.

NOTE — Below are listed the combinations of tolerance qualities IT corresponding to the combinations of tolerance units (i) indicated above. Those combinations of tolerance qualities IT are given only to indicate the conception principle of the tolerance system regarding its eventual extension, and **only to rediscover** the corresponding combinations of tolerance units (i).

Spline tolerance class	Tolerance quality (IT)
4	= (IT 6* + IT 9**)
5	= (IT 7* + IT 10**)
6	= (IT 8* + IT 11**)
7	= (IT 9* + IT 12**)

7 Basic rack profiles for spline

7.1 The basic rack is a section of the tooth surface of an in-

volute spline of infinitely large diameter on a plane at right angles to the tooth surfaces, the profile of which is used as the basis for defining the standard tooth dimensions of a system of involute splines.

7.2 The reference line is a straight line crossing the profile of the basic rack, with reference to which the tooth dimensions are specified.

7.3 The profile of the basic rack for the standard pressure angle splines is represented in the following figures :

figure 3 : 30° flat root spline, for modules 0,5 to 10;

figure 4 : 30° fillet root spline, for modules 0,5 to 10;

figure 5 : 37,5° fillet root spline, for modules 0,5 to 10;

figure 6 : 45° fillet root spline, for modules 0,25 to 2,5.

* Tolerance based on pitch diameter.

** Tolerance based on space width and tooth thickness.

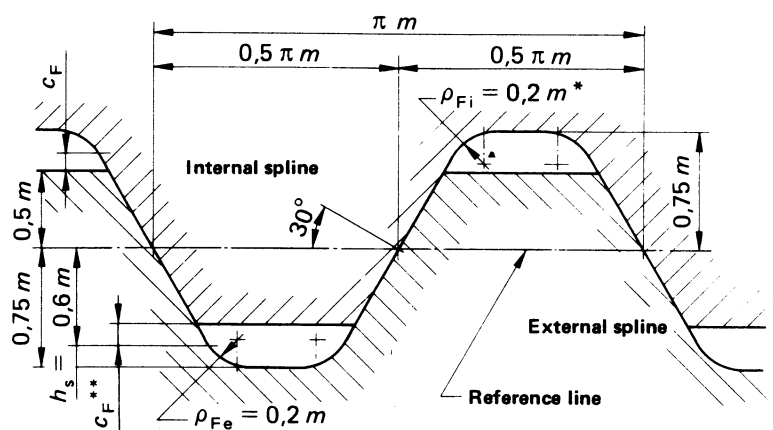


Figure 3 — Profile of the basic rack for 30° flat root spline

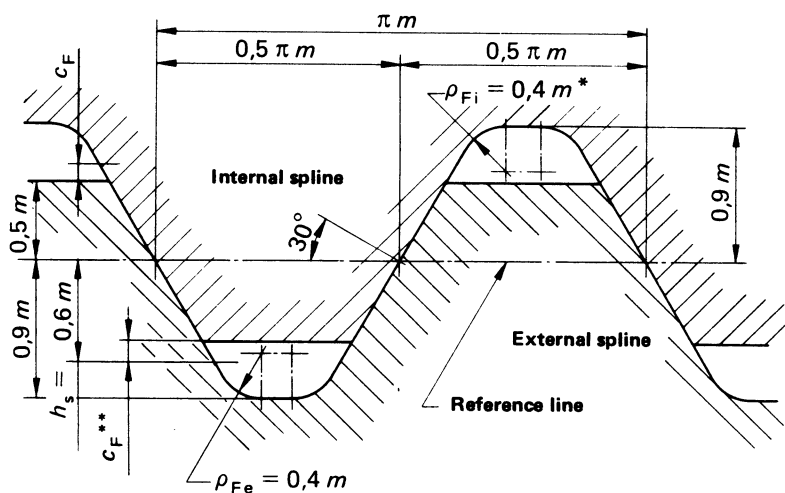


Figure 4 — Profile of the basic rack for 30° fillet root spline

* and ** See next page.

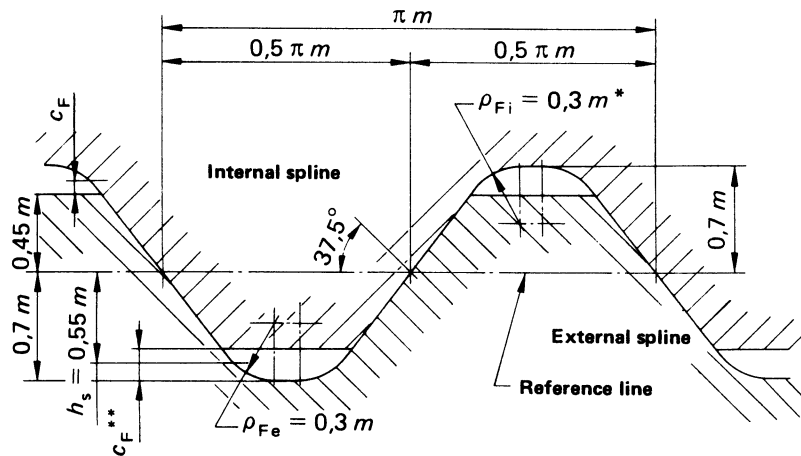


Figure 5 — Profile of the basic rack for 37.5° fillet root spline

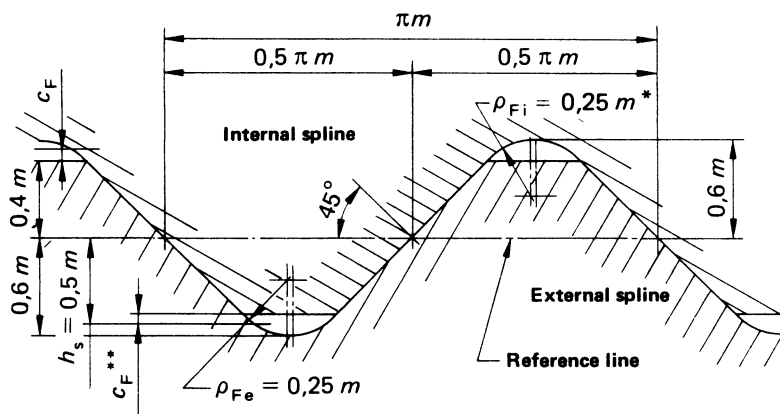


Figure 6 — Profile of the basic rack for 45° fillet root spline

NOTE concerning figures 3 to 6 :

* For internal splines (hub), the form diameter, obtained by generating from the basic rack, is always greater than the form diameter shown in the tables of dimensions (see section two), which corresponds in all fit cases to the major maximum diameter of the shaft (with upper deviation — es_v — zero) increased to diametral form clearance ($2 c_F$) equal to 0,2 module.

** For external splines (shafts), c_F is obtained by generation from the basic rack ($D_{Fe \max}$) and for H/h fit (see note 2 under table 2).

The size c_F indicated is in fact a deviation permitting the form clearance c_F given in table 2 to be obtained and is equal to 0,1 m.

7.4 The minimum radial form clearance, c_F , shown in the basic rack profiles is equal to $0,1 m$ for all pressure angle splines.

The form clearance is modified for fits other than H/h.

7.5 External splines may be produced by generating with a pinion-type shaper cutter or with a hob, or by cutting with no generating motion using a tool formed to the contour of a tooth space. External splines are also made by cold forming, and in these cases are usually of the fillet root design. Internal splines are usually produced by broaching, by form cutting, or by generating with a shaper cutter. Even when full tip radius tools are used, each of these cutting methods produces a fillet contour with individual characteristics. Generated spline fillets are curves related to the prolate epicycloid for external splines and the prolate hypocycloid for internal splines. These fillets have a minimum radius of curvature at the point where the fillet is tangent to the external spline minor diameter circle or the internal spline major diameter circle, and a rapidly increasing radius of curvature up to the point where the fillet becomes tangent to the involute profile.

The values in table 10 may be used as minimum radii of curvature for stress calculations and they may be specified as the minimum fillet radius. These values are based on the fillet radius shown on the basic rack profiles. For cutting of internal and external splines by generating, with the same pinion-type shaper cutter, the tool design will have to be made according to the dimensions of the internal splines to be obtained.

8 Machining tolerances and variations

8.1 Variation allowance (λ)

The variation allowance, being the addition of the total index variation, total profile variation and total lead variation, has an effect on the effective fit of an involute spline. The effect of these individual spline variations on the fit is less than their total, because areas of more than minimum clearance can have form, lead, or index errors without changing the fit. It is also unlikely that these errors would occur in their maximum amounts simultaneously on the same spline. For this reason, total index variation, profile variation and total lead variation are added together statistically and 60 % of this total is taken to determine the effect that these variations have on spline fit. On this basis, the variation allowance becomes as follows :

$$\lambda = 0,6 [(total\ index\ variation)^2 + (total\ profile\ variation)^2 + (total\ lead\ variation)^2]^{1/2}$$

The above variation allowance is based on a length of engagement equal to one-half the pitch diameter. Adjustment on the variation allowance may be required for a greater length of engagement.

8.2 Machining tolerance (T)

The machining tolerance (T) is derived from the difference between the total tolerance ($T + \lambda$) and the variation allowance (λ), i.e. $(T + \lambda) - \lambda$.

The division of total class tolerance between machining tolerance and variation allowance outlined in 8.1 and 8.2 is recommended for general guidance. Design requirements or specific processes utilized for spline manufacture may require a different division.

Table 3 — Variation allowance, λ — Modules 0,25 to 1

Values in micrometres

Z Number of teeth	m = 0,25				m = 0,50				m = 0,75				m = 1				Z Number of teeth																																				
	Tolerance class				Tolerance class				Tolerance class				Tolerance class																																								
	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7																																					
6	9	14	20	31	10	15	22	34	11	16	23	36	11	17	25	38	6																																				
7			21	32			23	35			24	37			26	39	8																																				
8																27	40	41	9																																		
9																			28	42	43	44	10																														
10	22	33			36	39			40	41			42	43									44	11																													
11			16	24			37	26			39	40			29									43	44	45	46	47	48	49	50	51	52	53	54	55																	
12																17	25	38																			13	18	27	41	20	29	43	44	30	45	33	49	55				
13																			34	12	26	39																												14	20	29	43
14	15	22			34	13			19	28			42	15									22																														
15			23	35			27	40			14	20			29									43	44	32	48	33	49	55																							
16																16	24	36													13	19	28	42	16	23	33	49	55														
17																			17	25	37	14																		20	29	43	44	34	50	51	52	53	54	55			
18	18	26			38	15			21	30			45	35									51																												52	53	54
19			19	27			39	16			22	31			46									50	51	52	53	54	55																								
20																20	28	40												17	23	32	47	50	51	52	53	54	55														
21																			21	29	41	18																		24	33	48	50	51	52	53	54	55					
22	22	30			42	19			25	34			49	50									51																										52	53	54	55	
23			23	31			43	20			26	35			50									51	52	53	54	55																									
24																24	32	44											21	27	36	51	52	53	54	55																	
25																			25	33	45	22															28	37	52	53	54	55											
26	26	34			46	23			29	38			53	54									55																														
27			27	35			47	24			30	39			54									55																													
28																28	36	48							25	31	40	55																									
29																			29	37	49	26							32	41																							
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37																37	45	57	34	40																																	
38	38	46			58	35			41																																												
39			39	47			59	36		42																																											
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42	42	50			62	39			45																																												
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46	46	54			66	43			49																																												
47			47	55			67	44		50																																											
48											48	56	68	45	51																																						
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59			59	67			79	56		62																																											
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170	170	178			190	167			173																																												
171			171	179			191	168		174																																											

Table 3 — Variation allowance, λ — Modules 0,25 to 1 (concluded)

Values in micrometres

Z Number of teeth	m = 0,25				m = 0,50				m = 0,75				m = 1				Z Number of teeth																																			
	Tolerance class				Tolerance class				Tolerance class				Tolerance class																																							
	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7																																				
56	13	19	27	41	16	23	33	49	18	26	37	55	20	29	41	60	56																																			
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74																												61	62																							
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76	15	21	30	44	18	25	36	53	20	28	40	59	22	31	45	66																																				
77																	44	52	35	51	20	28	40	59	22	31	45	66																								
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81	14	20	29	43	17	24	51	19	27	39	57	21	30	43	63																																					
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94																												61	62																							
95																														60	61																					
96	15	21	30	44	18	25	36	53	20	28	40	59	22	31	45	66																																				
97																	44	52	35	51	20	28	40	59	22	31	45	66																								
98																													64	52	35	51	20	28	40	59	22	31	45	66												
99																																									64	52	35	51	20	28	40	59	22	31	45	66
100																																																				

Table 4 — Variation allowance, λ — Modules 1,25 to 2

Values in micrometres

Values in micrometres																	
Z Number of teeth	m = 1,25				m = 1,5				m = 1,75				m = 2				Z Number of teeth
	Tolerance class				Tolerance class				Tolerance class				Tolerance class				
	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7	
6	12	18	26	40	13	18	27	41	13	19	28	43	14	20	29	44	6
7			27	42		20	29	44		30	45	7					
8			41	29		43	31	46		32	47	8					
9			42	20		44	31	47		32	48	9					
10	13	19	28	43	14	20	30	45	15	21	31	47	15	22	32	49	10
11			43	31		46	32	47		33	48	11					
12			44	31		47	34	50		35	51	12					
13			45	22		32	48	35		52	36	53		13			
14	14	20	30	46	15	22	32	48	16	23	33	50	17	24	35	52	14
15			31	47		34	51	36		54	15						
16			32	48		35	52	37		55	16						
17			33	49		36	53	38		56	17						
18	15	21	31	47	16	23	33	50	17	24	35	52	18	25	36	53	18
19			32	48		34	51	35		52	36	53		19			
20			33	49		35	52	36		53	37	54		20			
21			34	50		36	54	37		55	38	56		21			
22	16	22	32	48	17	24	34	51	18	25	36	53	19	26	37	54	22
23			33	49		35	52	37		54	38	56		23			
24			34	50		36	53	38		54	39	57		24			
25			35	51		37	54	39		55	40	58		25			
26	17	23	35	52	18	25	36	54	19	26	37	55	20	27	38	56	26
27			36	53		38	55	39		56	40	57		27			
28			37	54		39	56	40		57	41	58		28			
29			38	55		40	57	41		58	42	59		29			
30	18	24	36	53	19	26	37	55	20	27	38	56	21	28	39	57	30
31			37	54		38	56	40		57	41	58		31			
32			38	55		39	57	41		58	42	59		32			
33			39	56		40	58	42		59	43	60		33			
34	19	25	37	55	20	27	38	56	21	28	39	57	22	29	40	58	34
35			38	56		39	57	40		58	41	59		35			
36			39	57		40	58	41		59	42	60		36			
37			40	58		41	59	42		60	43	61		37			
38	20	26	38	56	21	28	39	57	22	29	40	58	23	30	41	59	38
39			39	57		40	58	41		59	42	60		39			
40			40	58		41	59	42		60	43	61		40			
41			41	59		42	60	43		61	44	62		41			
42	21	27	39	58	22	29	40	59	23	30	41	60	24	31	42	61	42
43			40	59		41	60	42		61	43	62		43			
44			41	60		42	61	43		62	44	63		44			
45			42	61		43	62	44		63	45	64		45			
46	22	28	40	60	23	30	41	60	24	31	42	61	25	32	43	62	46
47			41	61		42	62	43		63	44	64		47			
48			42	62		43	63	44		64	45	65		48			
49			43	63		44	64	45		65	46	66		49			
50	23	29	41	62	24	31	42	61	25	32	43	62	26	33	44	63	50
51			42	63		43	62	44		63	45	64		51			
52			43	64		44	63	45		64	46	65		52			
53			44	65		45	64	46		65	47	66		53			
54	24	30	42	63	25	32	43	62	26	33	44	63	27	34	45	64	54
55			43	64		44	63	45		64	46	65		55			
			44	65		45	64	46		65	47	66					
			45	66		46	65	47		66	48	67					
55	25	35	50	73	26	36	51	74	27	37	52	75	28	38	53	76	55

Table 4 — Variation allowance, λ — Modules 1,25 to 2 (concluded)

Values in micrometres

Z Number of teeth	m = 1,25				m = 1,5				m = 1,75				m = 2				Z Number of teeth
	Tolerance class				Tolerance class				Tolerance class				Tolerance class				
	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7	
56	22	31	45	65	23	33	48	70	25	35	51	74	26	37	53	78	56
57				66				71				75				79	57
58				67				72				76				80	58
59				68				73				77				81	59
60				69				74				78				82	60
61	23	32	46	67	24	34	49	72	26	36	52	76	27	38	55	80	61
62				68				73				77				81	62
63				69				74				78				82	63
64				70				75				79				83	64
65				71				76				80				84	65
66	24	33	47	68	25	35	50	73	27	37	53	77	28	39	56	82	66
67				69				74				78				83	67
68				70				75				79				84	68
69				71				76				80				85	69
70				72				77				81				86	70
71	25	34	48	69	26	36	51	74	28	38	54	79	29	40	57	83	71
72				70				75				79				84	72
73				71				76				80				85	73
74				72				77				81				86	74
75				73				78				82				87	75
76	26	35	50	70	27	37	52	76	29	39	55	80	30	41	58	85	76
77				71				76				80				85	77
78				72				77				81				86	78
79				73				78				82				87	79
80				74				79				83				88	80
81	27	36	51	71	28	38	53	77	30	40	56	82	31	42	59	86	81
82				72				77				81				86	82
83				73				78				82				87	83
84				74				79				83				88	84
85				75				80				84				89	85
86	28	37	52	72	29	39	54	78	31	41	57	83	32	43	60	87	86
87				73				78				82				87	87
88				74				79				83				88	88
89				75				80				84				89	89
90				76				81				85				90	90
91	29	38	53	73	30	40	55	79	31	42	58	84	32	44	61	88	91
92				74				79				83				88	91
93				75				80				84				89	92
94				76				81				85				90	93
95				77				82				86				91	94
96	30	39	54	74	31	41	56	80	32	43	59	85	33	45	62	89	92
97				75				80				84				89	93
98				76				81				85				90	94
99				77				82				86				91	95
100				78				83				87				92	96

Table 5 — Variation allowance, λ — Modules 2,5 to 5

Values in micrometres

Z Number of teeth	m = 2,5				m = 3				m = 4				m = 5				Z Number of teeth
	Tolerance class				Tolerance class				Tolerance class				Tolerance class				
	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7	
6	14	21	31	47	15	22	33	50	17	25	37	56	18	27	40	61	6
7	15	22	32	49	16	23	34	52	18	26	38	57	19	28	41	62	7
8		23	33	50		24	35	53		27	39	59	20	29	43	64	8
9	16		34	51	17		25	36	54		19	40	60	21	30	44	66	9
10		24	35	52		18	26	37	55	20		41	62	22	31	45	67	10
11	25		36	53	27		38	57	21		42	63	23	46	69	11	
12		54		58		20		43		64	32	47		70	12		
13	17	37	55	19	27	39	59	22	44	66	24	33	48	72	13		
14			28		40	60	31		45	67		34	49	73	14		
15	18	26		38	57	28		41	61	22	46		68	25	50	75	15
16		27	39	58	20		29	42	62		32	47	69		26	35	51	76	16
17	40		59	21		30	43	64	33	48		70	27	36		52	77	17
18		28	60		23	44	65	34		49	73	28		37	54	80	19
19	41		61	24		45	66		35	50	74		29	38	55	81	20
20		20	42		62	31	46	67		36	51	75		30	39	56	82
21	29		43	63	32		47	68	37		52	76	31		40	57	84
22		30	64	23		48	69	38		53	77	32		41	58	85	23
23	44		65		24	49	70		39	54	78		33	42	59	86	24
24		31	66	25		50	71	40		55	79	34		43	60	87	25
25	45		67		26	51	72		41	56	80		35	44	61	88	26
26		32	68	27		52	73	42		57	81	36		45	62	89	27
27	47		69		28	53	74		43	58	82		37	46	63	90	28
28		33	48	25		54	75	44		59	83	38		47	64	91	29
29	70				71	36	55		76	45	60		84	39	48	65	92
30		72	73	37			56	77	46		61	85	40		49	66	93
31	23				49	26	57	78		47	62	86		41	50	67	94
32		34	70	27	58		79	48	63		87	42	51		68	95	33
33	40		71		28	59	80		49	64	88		43	52	69	96	34
34		41	72	29		60	81	50		65	89	44		53	70	97	35
35	42		73		30	61	82		51	66	90		45	54	71	98	36
36		43	74	31		62	83	52		67	91	46		55	72	99	37
37	44		75		32	63	84		53	68	92		47	56	73	100	38
38		45	76	33		64	85	54		69	93	48		57	74	101	39
39	46		77		34	65	86		55	70	94		49	58	75	102	40
40		47	78	35		66	87	56		71	95	50		59	76	103	41
41	48		79		36	67	88		57	72	96		51	60	77	104	42
42		49	80	37		68	89	58		73	97	52		61	78	105	43
43	50		81		38	69	90		59	74	98		53	62	79	106	44
44		51	82	39		70	91	60		75	99	54		63	80	107	45
45	52		83		40	71	92		61	76	100		55	64	81	108	46
46		53	84	41		72	93	62		77	101	56		65	82	109	47
47	54		85		42	73	94		63	78	102		57	66	83	110	48
48		55	86	43		74	95	64		79	103	58		67	84	111	49
49	56		87		44	75	96		65	80	104		59	68	85	112	50
50		57	88	45		76	97	66		81	105	60		69	86	113	51
51	58		89		46	77	98		67	82	106		61	70	87	114	52
52		59	90	47		78	99	68		83	107	62		71	88	115	53
53	60		91		48	79	100		69	84	108		63	72	89	116	54
54		61	92	49		80	101	70		85	109	64		73	90		55
55	62		93		50	81	102		71	86	110		65	74	91		
		63	94	51		82	103	72		87	111	66		75	92		
	64		95		52	83	104		73	88	112		67	76	93		
		65	96	53		84	105	74		89	113	68		77	94		
	66		97		54	85	106		75	90	114		69	78	95		
		67	98	55		86	107	76		91	115	70		79	96		
	68		99		56	87	108		77	92	116		71	80	97		
		69	100	57		88	109	78		93		72		81	98		
	70		101		58	89	110		79	94			73	82	99		
		71	102	59		90	111	80		95		74		83	100		
	72		103		60	91	112		81	96			75	84	101		
		73	104	61		92	113	82		97		76		85	102		
	74		105		62	93	114		83	98			77	86	103		
		75	106	63		94	115	84		99		78		87	104		
	76		107		64	95	116		85	100			79	88	105		
		77	108	65		96		86		101		80		89	106		
	78		109		66	97			87	102			81	90	107		
		79	110	67		98		88		103		82		91	108		
	80		111		68	99			89	104			83	92	109		
		81	112	69		100		90		105		84		93	110		
	82		113		70	101			91	106			85	94	111		
		83	114	71		102		92		107		86		95	112		
	84		115		72	103			93	108			87	96	113		
		85	116	73		104		94		109		88		97	114		
	86				74	105			95	110			89	98	115		
		87		75		106		96		111		90		99	116		
	88				76	107			97	112			91	100			
		89		77		108		98		113		92		101			
	90				78	109			99	114			93	102			
		91		79		110		100		115		94		103			
	92				80	111			101	116			95	104			
		93		81		112		102				96		105			
	94				82	113			103				97	106			
		95		83		114		104				98		107			
	96				84	115			105				99	108			
		97		85		116		106				100		109			
	98				86				107				101	110			
		99		87				108				102		111			
	100				88				109				103	112			
		101		89				110				104		113			
	102				90				111				105	114			
		103		91				112				106		115			
	104				92				113				107	116			
		105		93				114				108					
	106				94				115				109				
		107		95				116				110					
	108				96								111				
		109		97								112					
	110				98								113				
		111		99								114					
	112				100								115				
		113		101								116					
	114				102												
		115		103													
	116				104												
				105													
					106												
				107													
					108												
				109													
					110												
				111													
					112												
				113													
					114												
				115													
					116												

Table 5 — Variation allowance, λ — Modules 2,5 to 5 (concluded)

Values in micrometres

Z Number of teeth	m = 2,5				m = 3				m = 4				m = 5				Z Number of teeth																							
	Tolerance class				Tolerance class				Tolerance class				Tolerance class																											
	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7																								
56	29	41	59	86	31	44	63	93	35	50	72	105	39	55	80	117	56																							
57				64			94	73			106	56				81	118																							
58																		82	119																					
59																				120																				
60	83	121																																						
61			42	60	57	84	122																																	
62								61	89	90	91	32	46	66	96	37	52	75	109		41	58	84	123																
63																				62					91	33	47	68	99	38	53	76	111	42	59	85	124			
64	63	92																																				100	39	54
65			64	93	101	40	55																																	
66								65	94	102	41	56	79	114	62	88	127																							
67																		66	95	103	42	57	80	115	63	89	128													
68	67	96																										104	43	58	81	116	64	90	129					
69			68	97	105	44	59																													82	117	65	91	130
70								69	98	106	45	60	83	118	66	92	131																							
71																		70	99	107	46	61	84	119	67	93	132													
72	71	100																										108	47	62	85	120	68	94	133					
73			72	101	109	48	63																													86	121	69	95	134
74								73	102	110	49	64	87	122	70	96	135																							
75																		74	103	111	50	65	88	123	71	97	136													
76	75	104																										112	51	66	89	124	72	98	137					
77			76	105	113	52	67																													90	125	73	99	138
78								77	106	114	53	68	91	126	74	100	139																							
79																		78	107	115	54	69	92	127	75	101	140													
80	79	108																										116	55	70	93	128	76	102	141					
81			80	109	117	56	71																													94	129	77	103	142
82								81	110	118	57	72	95	130	78	104	143																							
83																		82	111	119	58	73	96	131	79	105	144													
84	83	120																										120	59	74	97	132	80	106	145					
85			84	121	121	60	75																													98	133	81	107	146
86								85	122	122	61	76	99	134	82	108	147																							
87																		86	123	123	62	77	100	135	83	109	148													
88	87	124																										124	63	78	101	136	84	110	149					
89			88	125	125	64	79																													102	137	85	111	150
90								89	126	126	65	80	103	138	86	112	151																							
91																		90	127	127	66	81	104	139	87	113	152													
92	91	128																										128	67	82	105	140	88	114	153					
93			92	129	129	68	83																													106	141	89	115	154
94								93	130	130	69	84	107	142	90	116	155																							
95																		94	131	131	70	85	108	143	91	117	156													
96	95	132																										132	71	86	109	144	92	118	157					
97			96	133	133	72	87																													110	145	93	119	158
98								97	134	134	73	88	111	146	94	120	159																							
99																		98	135	135	74	89	112	147	95	121	160													
100	99	136																										136	75	90	113	148	96	122	161					
			100	137	137	76	91																													114	149	97	123	162
								101	138	138	77	92	115	150	98	124	163																							
																		102	139	139	78	93	116	151	99	125	164													
	103	140																										140	79	94	117	152	100	126	165					
			104	141	141	80	95																													118	153	101	127	166
								105	142	142	81	96	119	154	102	128	167																							
																		106	143	143	82	97	120	155	103	129	168													
	107	144																										144	83	98	121	156	104	130	169					
			108	145	145	84	99																													122	157	105	131	170
								109	146	146	85	100	123	158	106	132	171																							
																		110	147	147	86	101	124	159	107	133	172													
	111	148																										148	87	102	125	160	108	134	173					
			112	149	149	88	103																													126	161	109	135	174
								113	150	150	89	104	127	162	110	136	175																							
																		114	151	151	90	105	128	163	111	137	176													
	115	152																										152	91	106	129	164	112	138	177					
			116	153	153	92	107																													130	165	113	139	178
								117	154	154	93	108	131	166	114	140	179																							
																		118	155	155	94	109	132	167	115	141	180													
	119	156																										156	95	110	133	168	116	142	181					
			120	157	157	96	111																													134	169	117	143	182
								121	158	158	97	112	135	170	118	144	183																							
																		122	159	159	98	113	136	171	119	145	184													
	123	160																										160	99	114	137	172	120	146	185					
			124	161	161	100	115																													138	173	121	147	186
								125	162	162	101	116	139	174	122	148	187																							
																		126	163	163	102	117	140	175	123	149	188													
	127	164																										164	103	118	141	176	124	150	189					
			128	165	165	104	119																													142	177	125	151	190
								129	166	166	105	120	143	178	126	152	191																							
																		130	167	167	106	121	144	179	127	153	192													
	131	168																										168	107	122	145	180	128	154	193					
			132	169	169	108	123																													146	181	129	155	194
								133	170	170	109	124	147	182	130	156	195																							
																		134	171	171	110	125	148	183	131	157	196													
	135	172																										172	111	126	149	184	132	158	197					
			136	173	173	112	127																													150	185	133	159	198
								137	174	174	113	128	151	186	134	160	199																							
																		138	175	175	114	129	152	187	135	161	200													
	139	176																										176	115	130	153	188	136	162	201					
			140	177	177	116	131																													154	189	137	163	202
								141	178	178	117	132	155	190	138	164	203																							
																		142	179	179	118	133	156	191	139	165	204													
	143	180																										180	119	134	157	192	140	166	205					
			144	181	181	120	135																													158	193	141	167	206
								145	182	182	121	136	159	194	142	168	207																							
																		146	183	183	122	137	160	195	143	169	208													
	147	184																										184	123	138	161	196	144	170	209					
			148	185	185	124	139																													162	197	145	171	210
								149	186	186	125	140	163	198	146	172	211																							
																		150	187	187	126	141	164	199	147	173	212													
	151	188																										188	127	142	165	200	148	174	213					
			152	189	189	128	143																													166	201	149	175	214
								153	190	190	129	144	167	202	150	176	215																							
																		154	191	191	130	145	168	203	151	177	216													
	155	192																										192	131	146	169	204	152	178	217					
			156	193	193	132	147																													170	205	153	179	218
								157	194	194	133	148	171	206	154	180	219																							
																		158	195	195	134	149	172	207	155	181	220													
	159	196																										196	135	150	173	208	156	182	221					
			160	197	197	136	151																													174	209	157	1	

Table 6 — Variation allowance, λ — Modules 6 to 10

Values in micrometres

Z Number of teeth	m = 6				m = 8				m = 10				Z Number of teeth
	Tolerance class				Tolerance class				Tolerance class				
	4	5	6	7	4	5	6	7	4	5	6	7	
6	20	29	43	66	23	33	50	75	25	37	55	84	6
7	21	30	45	68		34	51	77	26	38	57	87	7
8		31	46	69	24	36	53	79	27	40	59	89	8
9	22	32	47	71	25	37	54	82	28	41	61	91	9
10	23	33	49	73	26	38	56	84	29	42	62	94	10
11		34	50	75	27	39	57	86	30	43	64	96	11
12	24	35	51	76		40	58	87		44	65	98	12
13	25	36	52	78	28	41	60	89	31	45	67	100	13
14			53	80	29	42	61	91	32	46	68	102	14
15	26	37	55	81			62	93	33	47	70	104	15
16		38	56	83	30	43	64	95		48	71	106	16
17	27	39	57	84	31	44	65	96	34	49	72	108	17
18			58	85		45	66	98	35	50	74	110	18
19	28	40	59	87	32	46	67	100		51	75	112	19
20		41	60	88		47	68	101	36	52	76	113	20
21	29		61	90	33	48	69	103	37	53	78	115	21
22		42		91			70	104		54	79	117	22
23	30	43	62	92	34	49	72	106	38	55	80	119	23
24			63	93	35	50	73	107	39		81	120	24
25	31	44	64	95			74	109		56	82	122	25
26		45	65	96	36	51	75	110	40	57	84	124	26
27	66		97	52		76	112	58		85	125	27	
28	32	46	67	98	37	53	77	113	41	59	86	127	28
29			68	100			78	114			87	128	29
30	33	47	69	101	38	54	79	116	42	60	88	130	30
31		48		102		55	80	117		61	89	131	31
32	34	49	70	103	39	56	81	119	43	62	90	133	32
33			71	104			120	44			91	134	33
34	35	50	72	105	40	57	82	121	45	63	92	136	34
35			73	106			83	122			93	137	35
36	36	51	74	107	41	58	84	124	46	65	94	139	36
37			75	109			85	125			95	140	37
38	37	52	76	110	42	59	86	126	47	66	96	142	38
39				111			87	127			97	143	39
40	38	53	77	112	43	60	88	129	48	67	98	144	40
41			78	113			89	130			99	146	41
42	39	54	79	114	44	61	90	131	49	68	100	147	42
43			80	115				91			132	101	149	43
44	40	55	81	116	45	62	92	133	50	69	102	150	44
45			82	117			93	134			103	151	45
46	41	56	83	118	46	63	94	135	51	70	104	153	46
47			84	119			95	136			105	154	47
48	42	57	85	120	47	64	96	137	52	71	106	155	48
49			86	121			97	138			107	156	49
50	43	58	87	122	48	65	98	139	53	72	108	159	50
51			88	123			99	140			109	160	51
52	44	59	89	124	49	66	99	141	54	73	110	161	52
53			90	125			100	142			111	163	53
54	45	60	91	126	50	67	100	143	55	74	112	164	54
55			92	127			101	144			113	165	55

Table 6 — Variation allowance, λ — Modules 6 to 10 (concluded)

Values in micrometres

Z Number of teeth	m = 6				m = 8				m = 10				Z Number of teeth								
	Tolerance class				Tolerance class				Tolerance class												
	4	5	6	7	4	5	6	7	4	5	6	7									
56	42	60	87	127	49	69	100	147	54	77	113	165	56								
57	43	61	88	128		70	101	148	55	78		166	57								
58			129	102								149	114	168	58						
59			89		130						115				169	59					
60	44	62	90		131	50	71	103	151	56						80	116	170	60		
61				132								72	104	152					57	81	118	172	62
62				63							91				133						
63	92	134	52		74	106	154	174	64												
64										45		64	93	135		53	75	107	155	175	65
65				94							136				54							76	108	156	176	66
66	65	95	137		55	77	109	157	177												
67										46		66	96	138		56	78	110	158	178	68
68				97							139				57							79	111	159	179	69
69	47	67	98		140	58	80	112	160																		180	70
70										99		141	59	81		113	161	181	71		
71				48							68				99					142	60	82	114	162	182	72
72	70	100	143		61	83	115	163	183												
73										49		71	101	144		62	84	116	164		
74				72							102				145					63	85
75	50	73	103		146	64	86	118	166																	186	76
76										74		104	147	65		87	119	167	187		
77				51							75				105					148	66
78	76	106	149		67	89	121	169	189												
79										52		77	107	150		68	90	122	170		
80				78							108				151					69	91
81	53	79	109		152	70	92	124	172																	192			82
82										79		110	153	71		93	125	173	193		
83				54							80				111					154	72
84	81	112	155		73	95	127	175	195												
85										55		82	113	156		74	96	128	176		
86				82							114				157					75	97
87	56	83	115		158	76	98	130	178																	198		88
88										83		116	159	77		99	131	179	199		
89				57							84				117					160	78
90	84	118	161		79	101	133	181	201												
91										58		85	119	162		80	102	134	182		
92				85							120				163					81	103	135	183	203	93
93	59	86	121		164	82	104	136	184																	204			94
94										86		122	165	83		105	137	185	205		
95				60							87				123					166	84
96	87	124	167		85	107	187	207	97												
97										61		88	125	168		86	108	188	208		
98				88							126				169					87	109
99	62	89	127		170	90	190	210	100												
100										63		90	128	171		91	191	211	101		
				64							91				129					172	92	192	212	102
	65	92	130		173	93	193	213	103												
										66		93	131	174		94	194	214	104		
				67							94				132					175	95	195	215	105
	68	95	133		176	96	196	216	106												
										69		96	134	177		97	197	217	107		
				70							97				135					178	98	198	218	108
	71	98	136		179	99	199	219	109												
										72		99	137	180		100	200	220	110		
				73							100				138					181	101	201	221	111
	74	101	139		182	102	202	222	112												
										75		102	140	183		103	203	223	113		
				76							103				141					184	104	204	224	114
	77	104	142		185	105	205	225	115												
										78		105	143	186		106	206	226	116		
				79							106				144					187	107	207	227	117
	80	107	145		188	108	208	228	118												
										81		108	146	189		109	209	229	119		
				82							109				147					190	110	210	230	120
	83	110	148		191	111	211	231	121												
										84		111	149	192		112	212	232	122		
				85							112				150					193	113	213	233	123
	86	113	151		194	114	214	234	124												
										87		114	152	195		115	215	235	125		
				88							115				153					196	116	216	236	126
	89	116	154		197	117	217	237	127												
										90		117	155	198		118	218	238	128		
				91							118				156					199	119	219	239	129
	92	119	157		200	120	220	240	130												
										93		120	158	201		121	221	241	131		
				94							121				159					202	122	222	242	132
	95	122	160		203	123	223	243	133												
										96		123	161	204		124	224	244	134		
				97							124				162					205	125	225	245	135
	98	125	163		206	126	226	246	136												
										99		126	164	207		127	227	247	137		
				100							127				165					208	128	228	248	138
	101	128	166		209	129	229	249	139												
										102		129	167	210		130	230	250	140		
				103							130				168					211	131	231	251	141
	104	131	169		212	132	232	252	142												
										105		132	170	213		133	233	253	143		
				106							133				171					214	134	234	254	144
	107	134	172		215	135	235	255	145												
										108		135	173	216		136	236	256	146		
				109							136				174					217	137	237	257	147
	110	137	175		218	138	238	258	148												
										111		138	176	219		139	239	259	149		
				112							139				177					220	140	240	260	150
	113	140	178		221	141	241	261	151												
										114		141	179	222		142	242	262	152		
				115							142				180					223	143	243	263	153
	116	143	181		224	144	244	264	154												
										117		144	182	225		145	245	265	155		
				118							145				183					226	146	246	266	156
	119	146	184		227	147	247	267	157												
										120		147	185	228		148	248	268	158		
				121							148				186					229	149	249	269	159
	122	149	187		230	150	250	270	160												
										123		150	188	231		151	251	271	161		
				124							151				189					232	152	252	272	162
	125	152	190		233	153	253	273	163												
										126		153	191	234		154	254	274	164		
				127							154				192					235	155	255	275	165
	128	155	193		236	156	256	276	166												
										129		156	194	237		157	257	277	167		
				130							157				195					238	158	258	278	168
	131	158	196		239	159	259	279	169												
										132		159	197	240		160	260	280	170		
				133							160				198					241	161	261	281	171
	134	161	199		242	162	262	282	172												
										135		162	200	243		163	263	283	173		
				136							163				201					244	164	264	284	174
	137	164	202		245	165	265	285	175												
										138		165	203	246		166	266	286	176		
				139							166				204					247	167	267	287	177
	140	167	205		248	168	268	288	178												
										141		168	206	249		169</					

8.3 Total index variation (F_p)

The total index variation is the cumulative pitch error between the two greatest opposite pitch errors over any sector of one half circumference. The total index variation (F_p) is a standard tolerance grade selection from ISO 1328, *Parallel involute gears — ISO System of accuracy*. The following formulae are used in this International Standard for the total index variation (F_p) expressed in micrometres :

Spline tolerance class	Total index variation (F_p) Formula
4	$2,5 \sqrt{L} + 6,3$
5	$3,55 \sqrt{L} + 9$
6	$5 \sqrt{L} + 12,5$
7	$7,1 \sqrt{L} + 18$

where length of arc $L = m Z \pi/2$.

8.4 Total profile variation (f_f)

The total profile variation is the amount of absolute values of the two greatest opposite variations of the flank surface irregularities of the actual profile that depart from the theoretical

profile. A positive variation is in the direction of the space, and a negative variation is in the direction of the tooth, as shown in figure 7. The total profile variation (f_f) is a standard tolerance grade selection from ISO 1328. The following formulae are used in this International Standard for the total profile variation (f_f) expressed in micrometres :

Spline tolerance class	Total profile variation (f_f) Formula
4	$1,6 \varphi_f + 10$
5	$2,5 \varphi_f + 16$
6	$4 \varphi_f + 25$
7	$6,3 \varphi_f + 40$

where tolerance factor $\varphi_f = m + 0,012 5 m Z$.

The permissible positive variation on external splines and the negative variation on internal splines from the design profile within the central one-third of the flank depth to the form diameter shall not exceed one-third of the calculated values. See figure 7.

NOTE — The middle point is situated on the involute at an equal distance from the major diameter of the external spline (D_{ee}) and from the minor diameter of the internal spline (D_{ii}). This point is the reference for the computation of pin diameters.

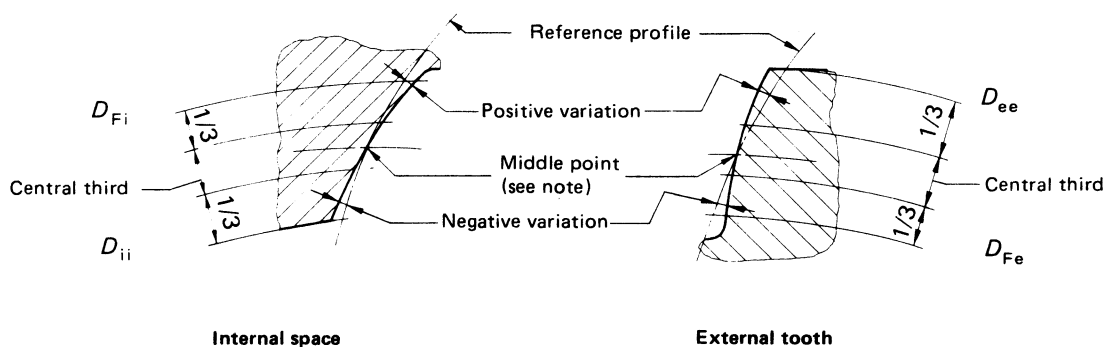


Figure 7 — Profile variations

8.5 Total lead variation (F_{β})

The total lead variation is the amount of absolute values of the two greatest opposite misalignment variations from the theoretical position, measured normal to the flank for the full length of spline. The total lead variation (F_{β}) is a standard tolerance grade selection from ISO 1328. The following formulae are used in this International Standard for the total lead variation (F_{β}), expressed in micrometres :

Spline tolerance class	Total lead variation (F_{β}) Formula
4	$0,8 \sqrt{g} + 4$
5	$1 \sqrt{g} + 5$
6	$1,25 \sqrt{g} + 6,3$
7	$2 \sqrt{g} + 10$

where g is the spline length, in millimetres.

8.6 Out-of-roundness

This condition may appear merely as a result of total index and total profile variations described in 8.3 and 8.4, and requires no further allowance. However, heat treatment and deflection of thin sections may cause out-of-roundness, which increases total index and total profile variations. Tolerances for such conditions depend on many variables, and are therefore not tabulated. Additional tooth and space width tolerance must allow for such conditions.

8.7 Eccentricity

8.7.1 Eccentricity of major and minor diameters, in relation to the effective reference diameter of side fit splines, should not cause contact beyond the form diameters of the mating splines, even under conditions of maximum effective clearance. This International Standard does not establish specific tolerances.

8.7.2 Deviation allowance from an H/h fit (without looseness or interference). If working conditions require looseness or interference, and the alignment of mating splines is affected by eccentricity of locating surfaces relative to each other and/or the splines, it may be necessary to prescribe a minimum effective clearance by decreasing the effective and actual tooth thickness of the external spline by an amount sufficient to allow the misaligned splines to assemble.

8.7.2.1 This International Standard provides standard deviation allowance $k - j_s - h - f - e$ and d for application to the circular tooth thickness at the pitch diameter (S) of the external

spline in order to establish the spline fit classes without looseness or having maximum effective interferences or minimum effective clearances (see table 7) and thus standardizing on composite GO gauges. Figure 8 represents in graphical form the deviation allowances and spline class tolerance zones for the six spline fit classes as outlined in 5.2.

8.7.2.2 Application of deviation allowance

The spline tables in section two of this International Standard are based on spline fit class H/h, which has a minimum effective clearance equal to zero. Selection of a spline fit class having a different deviation allowance requires adjustment to the external spline dimensions as follows :

a) For the deviation allowance selected ($k - j_s - h - f - e$ and d), determine the upper deviation value (es_v) from table 7.

b) Adjust the maximum effective tooth thickness, $S_{v \max}$, and the minimum actual tooth thickness, $S_{\min}$, specified in the spline tables, by the amount of the upper deviation value (es_v) shown in section two.

c) Adjust major diameter and minor minimum and maximum diameters (D_{ee} , $D_{ie \min}$ and $D_{ie \max}$) from the value given in table 8 for each deviation allowance and each pressure angle.

For fit classes H/k and H/ j_s , a null value of upper deviation (es_v) for the major diameter of the external spline (D_{ee}) will have to be taken.

d) Calculate minimum and maximum dimensions over two pins, external spline ($M_{Re \min}$ and $M_{Re \max}$) :

$$M_{Re \min} = M_{Re \min}^* + (es_v) K_e$$

$$M_{Re \max}^{**} = M_{Re \min}^* + (es_v + T) K_e$$

Values of the factor K_e are given in section three. These formulae are approximate (see section three; clause . . . , approximation factor). In case of dispute, only calculated values according to the formulae stated in section three, clauses . . . to . . . (concerning dimensions between or over pins) shall be taken into consideration.

Upper deviation (es_v) values are given in table 7.

e) Calculate the minimum and maximum dimensions over k teeth, external spline ($W_{\min}$ and $W_{\max}$).

Values of minimum and maximum dimensions over k teeth are given for the fit class H/h in section three — Inspection — clause . . . For other fit classes, apply the corresponding formulae in section three, clause . . .

* $M_{Re \min}$ values corresponding to values of fit class H/h (see section three).

** $M_{Re \max}$ values corresponding to the maximum actual limits (machining).

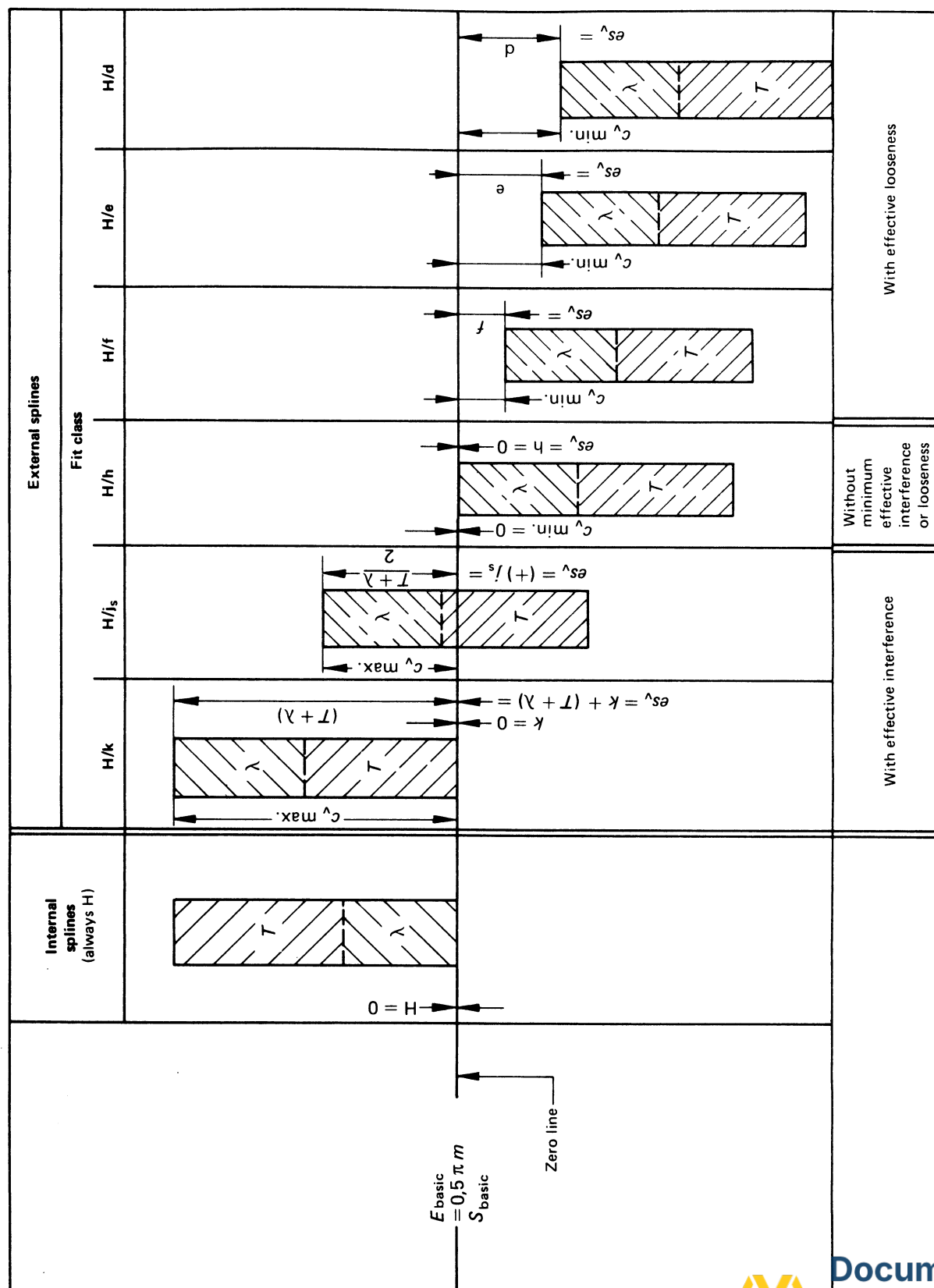


Figure 8 — Graphical representation of deviation allowances for the spline fit classes

Table 7 — Limit deviations (es_v) resulting from fundamental deviations1 μm = 0,001 mm

Pitch diameter D mm	External splines						Internal splines
	Upper deviation relative to basic tooth thickness, S , at pitch diameter, μm						Lower deviation relative to basic space width at pitch diameter, μm
	For fundamental deviations						
	d	e	f	h	i_s	k	H
≤ 3	– 20	– 14	– 6	0	plus $\frac{S_v \max - S_{\min}}{2}$ relative to tolerance class considered 1)	plus $S_v \max - S_{\min}$ relative to tolerance class considered 1)	0
> 3 to 6	– 30	– 20	– 10	0			0
> 6 to 10	– 40	– 25	– 13	0			0
> 10 to 18	– 50	– 32	– 16	0			0
> 18 to 30	– 65	– 40	– 20	0			0
> 30 to 50	– 80	– 50	– 25	0			0
> 50 to 80	– 100	– 60	– 30	0			0
> 80 to 120	– 120	– 72	– 36	0			0
> 120 to 180	– 145	– 85	– 43	0			0
> 180 to 250	– 170	– 100	– 50	0			0
> 250 to 315	– 190	– 110	– 56	0			0
> 315 to 400	– 210	– 125	– 62	0			0
> 400 to 500	– 230	– 135	– 68	0			0
> 500 to 630	– 260	– 145	– 76	0			0
> 630 to 800	– 290	– 160	– 80	0			0
> 800 to 1 000	– 320	– 170	– 86	0			0

1) For $S_v \max$ and $S_{\min}$, see section two — tables of dimensions.

Basic tooth thickness, S , and basic space width e at pitch diameter, mm			
Module 0,25 = 0,393	Module 1,25 = 1,963	Module 2,5 = 3,927	Module 6 = 9,425
Module 0,5 = 0,785	Module 1,5 = 2,356	Module 3 = 4,712	Module 8 = 12,566
Module 0,75 = 1,178	Module 1,75 = 2,749	Module 4 = 6,283	Module 10 = 15,708
Module 1 = 1,571	Module 2 = 3,142	Module 5 = 7,854	

Table 8 — Reduction for minor and major diameters (D_{ie} and D_{ee}) of external splines resulting from fundamental deviations

1 μm = 0,001 mm

Pitch diameter D mm	$es_v/\tan \alpha_D, \mu\text{m, for}$											
	d			e			f			h	i_s	k
	30°	$37,5^\circ$	45°	30°	$37,5^\circ$	45°	30°	$37,5^\circ$	45°	α_D	α_D	α_D
≤ 3	- 35	- 26	- 20	- 24	- 18	- 14	- 10	- 8	- 6	0	plus quotient of $\frac{S_{V \max} - S_{V \min}}{2}$ by $\tan \alpha_D 1^\circ$	plus quotient of $S_{V \max} - S_{V \min}$ by $\tan \alpha_D 1^\circ$
> 3 to 6	- 52	- 39	- 30	- 35	- 26	- 20	- 17	- 13	- 10	0		
> 6 to 10	- 69	- 52	- 40	- 43	- 33	- 25	- 23	- 17	- 13	0		
> 10 to 18	- 87	- 65	- 50	- 55	- 42	- 32	- 28	- 21	- 16	0		
> 18 to 30	- 113	- 85	- 65	- 69	- 52	- 40	- 35	- 26	- 20	0		
> 30 to 50	- 139	- 104	- 80	- 87	- 65	- 50	- 43	- 33	- 25	0		
> 50 to 80	- 173	- 130	- 100	- 104	- 78	- 60	- 52	- 39	- 30	0		
> 80 to 120	- 208	- 156	- 120	- 125	- 94	- 72	- 62	- 47	- 36	0		
> 120 to 180	- 251	- 189	- 145	- 147	- 111	- 85	- 74	- 56	- 43	0		
> 180 to 250	- 294	- 222	- 170	- 173	- 130	- 100	- 87	- 65	- 50	0		
> 250 to 315	- 329	- 248	- 190	- 191	- 143	- 110	- 97	- 73	- 56	0		
> 315 to 400	- 364	- 274	- 210	- 217	- 163	- 125	- 107	- 81	- 62	0		
> 400 to 500	- 398	- 300	- 230	- 234	- 176	- 135	- 118	- 89	- 68	0		
> 500 to 630	- 450	- 339	- 260	- 251	- 189	- 145	- 132	- 99	- 76	0		
> 630 to 800	- 502	- 378	- 290	- 277	- 209	- 160	- 139	- 104	- 80	0		
> 800 to 1 000	- 554	- 417	- 320	- 294	- 222	- 170	- 149	- 112	- 86	0		

1) For $S_{v \max}$ and $S_{v \min}$ see section two — tables of dimensions.

$\tan \alpha_D 30^\circ = 0,577\ 33$

$\tan \alpha_D 37,5^\circ = 0,767\ 33$

$\tan \alpha_D 45^\circ = 1$

Table 9 — Tolerances for minor diameter — internal spline (D_{ii})
Tolerances for major diameter — external spline (D_{ee})

1 μm = 0,001 mm

Diameter D_{ii} min or D_{ee} max mm	Tolerances for D_{ii} , μm for modules m			Tolerances for D_{ee} , μm for modules m		
	0,25 to 0,75	1 to 1,75	2 to 10	0,25 to 0,75	1 to 1,75	2 to 10
	H10	H11	H12	h10	h11	h12
≤ 3	+ 40 0			0 - 40		
> 3 to 6	+ 48 0	+ 75 0		0 - 48	0 - 75	
> 6 to 10	+ 58 0	+ 90 0		0 - 58	0 - 90	
> 10 to 18	+ 70 0	+ 110 0	+ 180 0	0 - 70	0 - 110	0 - 180
> 18 to 30	+ 84 0	+ 130 0	+ 210 0	0 - 84	0 - 130	0 - 210
> 30 to 50	+ 100 0	+ 160 0	+ 250 0	0 - 100	0 - 160	0 - 250
> 50 to 80	+ 120 0	+ 190 0	+ 300 0	0 - 120	0 - 190	0 - 300
> 80 to 120		+ 220 0	+ 350 0		0 - 220	0 - 350
> 120 to 180		+ 250 0	+ 400 0		0 - 250	0 - 400
> 180 to 250			+ 460 0			0 - 460
> 250 to 315			+ 520 0			0 - 520
> 315 to 400			+ 570 0			0 - 570
> 400 to 500			+ 630 0			0 - 630
> 500 to 630			+ 700 0			0 - 700
> 630 to 800			+ 800 0			0 - 800
> 800 to 1 000			+ 900 0			0 - 900

TABLE 10 – Minimum fillet radius of internal or external splines resulting from fillet radius of basic racks (see 7.5)

Module	Minimum radius, mm, for			
	$\alpha_D = 30^\circ$ (fig. 3)	$\alpha_D = 30^\circ$ (fig. 4)	$\alpha_D = 37,5^\circ$ (fig. 5)	$\alpha_D = 45^\circ$ (fig. 6)
<i>m</i>	0,2 <i>m</i>	0,4 <i>m</i>	0,3 <i>m</i>	0,25 <i>m</i>
10	2,00	4,00	3,00	
8	1,60	3,20	2,40	
6	1,20	2,40	1,80	
5	1,00	2,00	1,50	
4	0,80	1,60	1,20	
3	0,60	1,20	0,90	
2,5	0,50	1,00	0,75	0,62
2	0,40	0,80	0,60	0,50
1,75	0,35	0,70	0,52	0,44
1,5	0,30	0,60	0,45	0,38
1,25	0,25	0,50	0,38	0,31
1	0,20	0,40	0,30	0,25
0,75	0,15	0,30	0,22	0,19
0,5	0,10	0,20	0,15	0,12
0,25				0,06

8.7.2.3 In the manufacture of external splines with a standard deviation allowance, standard cutters conforming to the basic rack can be used by shifting the basic rack reference line radially from its position touching the spline pitch circle. The spline tooth profiles remain as involutes; merely different parts of the same involutes, lying further inward or outward with respect to the pitch circle, are used. The amount of this radial displacement is equivalent to $0,5 \, es_v / \tan \alpha_D$.

8.7.2.4 The effect of the various magnitudes of upper deviation (es_v) on the tooth form have an effect on the circular tip thickness, at the major diameter of the external spline, which varies when the upper deviation (es_v) varies. The following checks should be made when applying deviation allowances :

- a) Check for tip thickness at major maximum diameter of external spline

Tip thickness less than 0,25 *m* should be avoided. Tip thickness is computed as follows, considering $D_{ee \max}$

$$S_{ee} = D_{ee \max} [(S_{\min}/D) + \text{inv } \alpha_D - \text{inv } \alpha_{Dee}]$$

where

S_{ee} is the tip thickness;

α_D is the pressure angle at the pitch diameter;

α_{Dee} is the pressure angle at the maximum major diameter, $\cos \alpha_{Dee} = D_b/D_{ee \max}$

$$\text{inv } \alpha_D = \tan \alpha_D - \alpha_D$$

$$\text{inv } \alpha_{Dee} = \tan \alpha_{Dee} - \alpha_{Dee}$$

$S_{\min}$ is the minimum actual tooth thickness resulting from the deviation allowance.

- b) Undercut fillet at the root circle (interference)

When a fit with looseness is selected, generating tools may produce undercut fillets on the external spline. Calculation using the appropriate tool data should be made to establish the presence or absence of undercutting and, if it exists, further calculations or a layout are then required to determine whether the degree of undercutting is acceptable.

Low tooth numbers and pressure angles introduce the risk of undercutting which occurs with basic rack generation when :

$$(h_s + 0,5 \Delta D_{ie}) > 0,5 D \sin^2 \alpha_D$$

9 Effect of spline variations

9.1 Index variations

These variations cause looseness or interference from one set of mating tooth sides to another. Since the fit depends on the areas with minimum looseness or interference, index variations reduce the effective looseness or increase the effective interference.

9.2 Profile variations (see figure 7)

Profile variations reduce contact area. Positive profile variations affect the fit by reducing effective looseness. Negative profile variations do not affect the effective looseness.

9.3 Lead variations

The variations cause clearance variations and therefore reduce the effective looseness.

10 Effective and actual dimensions for splines

10.1 Effective and actual space width

Figure 9 a) illustrates an internal spline with variations of index and profile. Figure 9 b) shows that a perfect external spline contour (without variations) does not fit, even though each tooth has the same width as the mating space. To allow the perfect external spline to fit in any position, all spaces of the internal spline must be widened by the amount of interference. This width, as shown in figure 9 c), is the actual space width of the internal spline. The effective space width is the tooth thickness of the perfect mating spline.

10.2 Effective and actual tooth thickness

The same reasoning applied to the external spline leads to the concept of effective tooth thickness which exceeds the actual tooth thickness by the effective variation (see figure 10).

10.3 Effective clearance (looseness or interference)

The effective space width of the internal spline minus the effective tooth thickness of the external spline is the effective clearance (looseness or interference), which defines the fit of mating parts. (This is strictly true only if high points — crests — of mating parts come into contact.) Positive effective clearance represents looseness or backlash; negative effective clearance represents tightness or interference.

10.4 Space width and tooth thickness limits

The variations of the actual space width and actual tooth thickness within the machining tolerance cause corresponding variations of their effective dimensions. Thus, there are four limit dimensions for space width (minimum effective, maximum effective, minimum actual and maximum actual) and four limit dimensions for tooth thickness (maximum effective, minimum effective, maximum actual and minimum actual), as illustrated in figure 11.

10.4.1 The minimum effective space width ($E_{v \min}$), maximum effective tooth thickness ($S_{v \max}$), and minimum effective clearance ($c_{v \min}$) for the spline fit class H/h are as follows :

$$E_{v \min} = S_{v \max} = 0,5 \pi m (E_{\text{basic}} \text{ or } S_{\text{basic}})$$

$$c_{v \min} = 0 \text{ (no backlash).}$$

10.4.2 The maximum effective space width ($E_{v \max}$), minimum effective tooth thickness ($S_{v \min}$), and maximum effective clearance ($c_{v \max}$) for the spline fit class H/h are as follows :

$$E_{v \max} = 0,5 \pi m + T$$

$$S_{v \min} = 0,5 \pi m - T$$

$$c_{v \max} = 2 T$$

10.4.3 The minimum actual space width ($E_{\min}$), maximum actual tooth thickness ($S_{\max}$), and minimum theoretical clearance ($c_{\min}$) for spline fit class H/h are as follows :

$$E_{\min} = 0,5 \pi m + \lambda$$

$$S_{\max} = 0,5 \pi m - \lambda$$

$$c_{\min} = 2 \lambda$$

10.4.4 The maximum actual space width ($E_{\max}$), minimum actual tooth thickness ($S_{\min}$), and maximum theoretical clearance ($c_{\max}$) for spline fit class H/h are as follows :

$$E_{\max} = 0,5 \pi m + (T + \lambda)$$

$$S_{\min} = 0,5 \pi m - (T + \lambda)$$

$$c_{\max} = 2 (T + \lambda)$$

10.4.5 Where the external spline has a deviation allowance other than h, the above effective and theoretical values, c_v and c (in 10.4.1 to 10.4.4) must be modified by the amount of the quantity resulting from these deviation allowances (see table 7).

11 Use of effective and actual dimensions for space width and tooth thickness

11.1 Minimum effective space width and maximum effective tooth thickness

These dimensions define the maximum material condition which ensures that the splines will assemble. These dimensions shall be specified for all splines inspected by composite spline GO gauges controlling the minimum effective clearance ($c_{v \min}$).

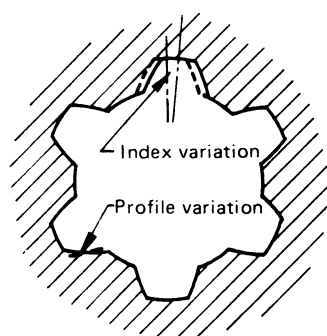
11.2 Minimum actual space width and maximum actual tooth thickness

These dimensions should be specified as auxiliary dimensions (AUX) and are not used for acceptance or rejection of parts inspected by composite spline GO gauges controlling the maximum material limit. If the measured actual space width is less than the auxiliary minimum actual space width, and the internal spline accepts the composite plug GO gauge, or if the measured actual tooth thickness is more than the auxiliary maximum actual tooth thickness, and the external spline accepts the composite ring GO gauge, the cumulative effect of the individual spline variation errors is less than the variation allowance λ ; such parts are acceptable because the maximum material condition has not been exceeded. The specification of these actual dimensions as auxiliary dimensions is desirable in order to control space width size and tooth thickness size.

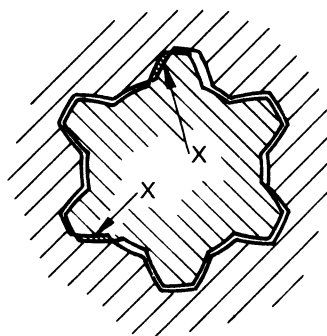
The machining tolerance includes all variations of section. Any variation of section will affect tooth thickness and flank parallelism measurements.

11.3 Maximum actual space width and minimum actual tooth thickness

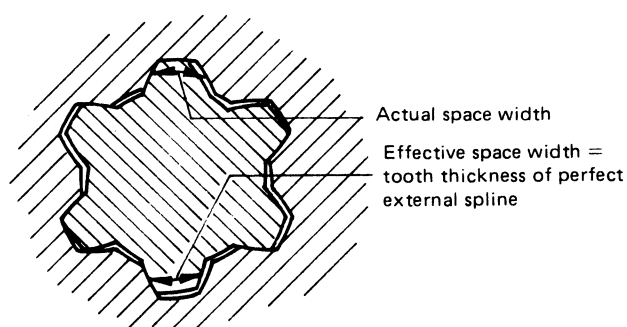
These dimensions define the minimum material condition and shall be specified for all splines for acceptance or rejection of parts.



a) Each space is basic width

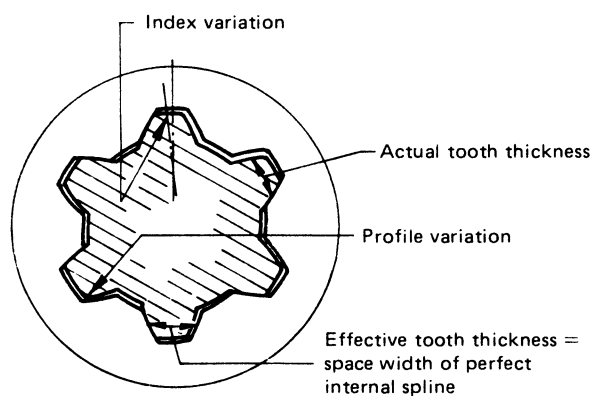


b) The perfect external spline with basic tooth thickness interference at X



c) The perfect external spline fits in any position, if all spaces are widened by the amount of the interference

Figure 9 — Effect of variations on internal spline



The perfect internal spline fits in any position, if all teeth of the external spline are narrowed by the amount of the interference

Figure 10 — Effect of variations on external spline

	Piece		Inspection		
	actual	effective	Standard method	Alternative A	Alternative B
$E_{\max}$ (actual space width)			Size between pins 	Size between pins 	AUX only
$E_{\min}$			AUX or size between pins	AUX only	AUX only
$E_{v\max}$			AUX only		
$E_{\text{basic}} (0,5 \pi m)$ or S_{basic}			GO composite plug 	GO composite plug 	GO composite plug
$E_{v\min}$ (effective space width)					
$S_{v\max}$ (effective tooth thickness)			GO composite ring 	GO composite ring 	GO composite ring
$s_{v\min}$			AUX only	NOT GO composite ring 	NOT GO composite ring
$s_{\max}$			AUX or sizes over pins	AUX only	AUX only
$S_{\min}$ (actual tooth thickness)			NOT GO sector ring 	NOT GO sector ring 	AUX only
			Size over pins	Size over pins	

Figure 11 — Specification guide for space width and tooth thickness for splines

11.4 Maximum effective space width and minimum effective tooth thickness

These dimensions define the maximum effective clearance for spline fit class H/h, but they do not limit the effective variation.

11.4.1 They may be used, in addition to the limits of 11.3, in order to prevent the increase of maximum effective clearance, due to reduction of effective variations. See figure 11, alternative method A. This method requires inspection by NOT GO composite gauges as well as GO composite gauges, which increases the gauging requirements. The notation "inspection optional" may be added where maximum effective clearance is an assembly requirement, but does not need absolute control. It will indicate, without necessarily adding inspection time and equipment, that in this case the actual space width of the internal spline must be held below the maximum, or the actual tooth thickness of the external spline above the minimum, if machining methods result in less than allowable variations.

11.4.2 Where spline variations require no control, alternative method B shown in figure 11 shall be used. When alternative method B is used and it is necessary to control the spline variations by laboratory inspection, the following data shall be added to the spline specifications :

- | | |
|--|------------|
| a) total involute profile variation | 0,0XX |
| positive variation within central one-third of flank depth | + 0,0XX |
| b) total index variation over any sector of one-half circumference | 0,0XX max. |
| c) total lead variation, $g_y = XX,XX$ | 0,0XX |

These values result from the formulae given in 8.3, 8.4 and 8.5.

12 Drawing data

It is important that uniform specifications be used to show complete information on detail drawings of splines. Much misunderstanding will be avoided by following the suggested arrangement of dimensions and data, as shown on data sheets. The number of X s indicates the number of decimal places normally used. With this charted type of spline specifications, it is usually not necessary to give a graphical illustration of the spline teeth.

12.1 Spline data and basic dimensions

Spline data are used for engineering and manufacturing purposes. Pitch and pressure angle are not subject to individual inspection. Basic dimensions are defined in 2.45.

12.2 Combinations of types

12.2.1 Flat root side fit internal splines may be used with fillet root external splines where the larger radius is desired on the external spline for control of stress concentrations. This combination of spline roots may also be permitted as a design option by specifying, for the minimum root diameter of the external spline, the value of the minimum root diameter of the fillet root external spline, and noting this as "optional root".

12.2.2 A design option may also be permitted to provide either flat root internal or fillet root internal by specifying, for the maximum major diameter, the value of the maximum major diameter of the fillet root internal spline and noting this as "optional root".

NOTE (concerning 12.2.1 and 12.2.2) — The major diameter of a flat root internal spline and, if needed, the diameter at the tangence point of radius, should be placed between the form diameter and the maximum major diameter of the fillet root internal spline.

In all cases, the GO gauge should be accepted by the piece.

12.3 Designation

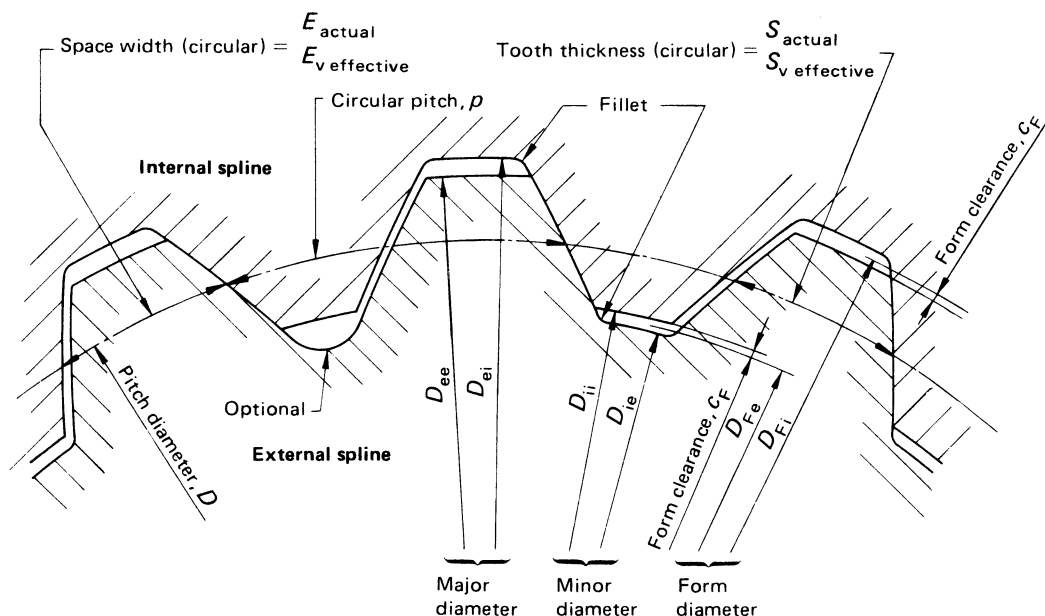
The mating parts of straight cylindrical involute splines (metric module, side fit) are designated in the following order :

- | | |
|-------------------------------|--------------------------------------|
| a) Internal spline | = INT |
| External spline | = EXT |
| Mating splines | = INT/EXT |
| b) Number of teeth | = Z (preceded by the number) |
| c) Module | = m (preceded by the value) |
| d) Pressure angle = | |
| 30° flat root | = 30 P |
| Pressure angle = | |
| 30° fillet root | = 30 R |
| Pressure angle = | |
| 37,5° | = 37,5 |
| Pressure angle = | |
| 45° | = 45 |
| e) Tolerance classes | = 4 — 5 — 6 — 7 |
| f) Fit class, internal spline | = H |
| Fit classes, external spline | = k — j _s — h — f — e — d |
| g) ISO 4156 | |

Example : Mating splines, 24 teeth — module 2,5 — pressure angle 30° fillet root — tolerance class 5 — fit H/f
mating : INT/EXT 24Z × 2,5 m × 30R × 5H/5f
ISO 4156

internal spline : INT 24Z × 2,5 m × 30R × 5H
ISO 4156

external spline : EXT 24Z × 2,5 m × 30R × 5f
ISO 4156

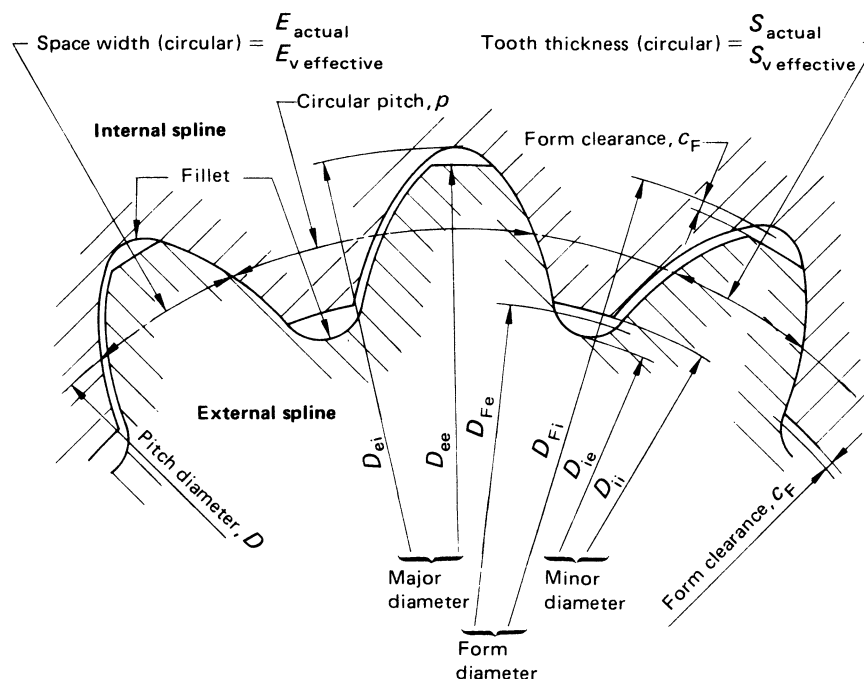
Figure 12 — Flat root spline — Pressure angle $\alpha_D = 30^\circ$ — Modules 0,5 to 10Table 11 — Spline terms, symbols and drawing data, 30° pressure angle, flat root side fit

Internal spline			External spline		
Number of teeth	Z	.....	Number of teeth	Z	.....
Module	m	.....	Module	m	.....
Pressure angle	α_D	30°	Pressure angle	α_D	30°
Base diameter	D_b	xx,xxxx Ref*	Base diameter	D_b	xx,xxxx
Pitch diameter	D	xx,xxxx Ref*	Pitch diameter	D	.....
Major diameter	D_{ei}	{ xx,xx max. xx,xx min.	Major diameter	D_{ee}	xx,xx — tol. h...
Form diameter	D_{Fi}	xx,xx min.	Form diameter	D_{Fe}	xx,xx max.
Minor diameter	D_{ii}	xx,xx + tol. H...	Minor diameter	D_{ie}	{ xx,xx min. xx,xx max.
Base pitch	p_b	xx,xxxx	Base pitch	p_b	xx,xxxx
Circular space width			Circular tooth thickness		
max. actual	$E_{\max}$	xx,xxx	max. effective	$S_{v \max}$	xx,xxx
min. actual	$E_{\min}$	xx,xxx Ref*	min. effective	$S_{v \min}$	xx,xxx
max. effective	$E_{v \max}$	xx,xxx	max. actual	$S_{\max}$	xx,xxx Ref*
min. effective	$E_{v \min}$	xx,xxx	min. actual	$S_{\min}$	xx,xxx
Measurement between pins	M_{Ri}	xx,xxx-xx,xxx	Measurement over pins	M_{Re}	xx,xxx-xx,xxx
Pin diameter	D_{Ri}	x,xxx	Pin diameter	D_{Re}	xx,xxx
Fillet radius	see table 10		Fillet radius	see table 10	

* Non measurable or values measurable with difficulty used for determination of dimensions to be controlled.

The above drawing data are required for the spline specifications. The standard system is shown; for control alternatives and combinations of types, see 11.4 and 12.2.

This fit is used in restricted areas (as with tubular parts with wall thickness too small to permit use of fillet roots, and to allow hobbing closer to shoulders, etc.) and for economy (when hobbing, shaping, etc. and shorter broaches for the internal member). See section two, tables 16 to 43.

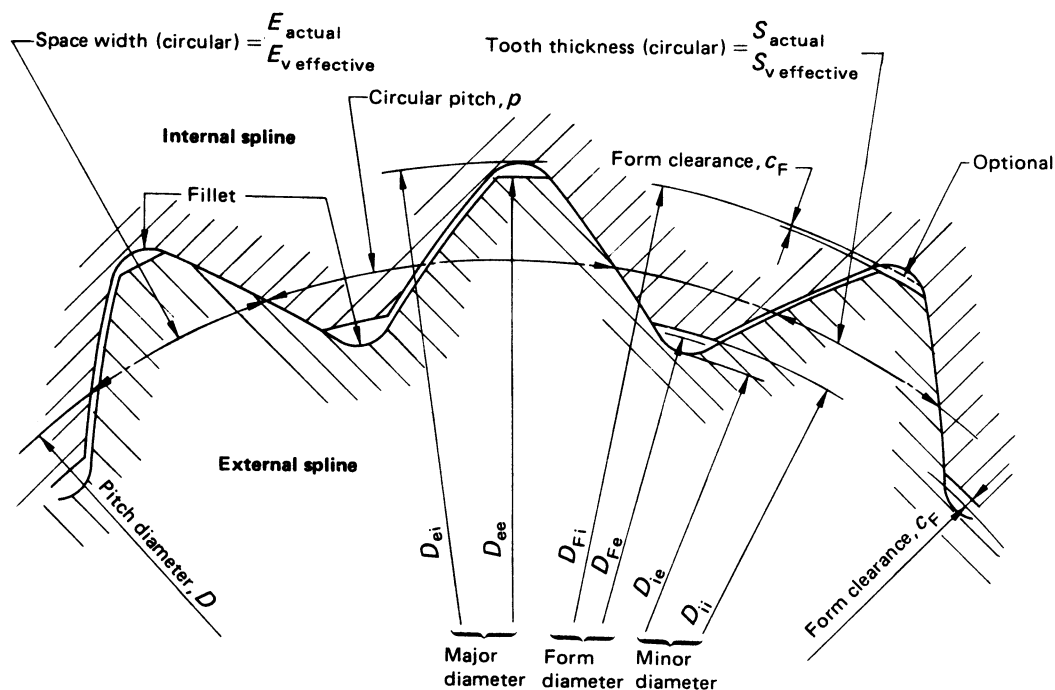
Figure 13 — Fillet root spline — Pressure angle $\alpha_D = 30^\circ$ — Modules 0,5 to 10Table 12 — Spline terms, symbols and drawing data, 30° pressure angle, fillet root side fit

Internal spline			External spline		
Number of teeth	Z	.....	Number of teeth	Z	.....
Module	m	.....	Module	m	.....
Pressure angle	α_D	30°	Pressure angle	α_D	30°
Base diameter	D_b	xx,xxx Ref*	Base diameter	D_b	xx,xxx
Pitch diameter	D	xx,xxx Ref*	Pitch diameter	D	xx,xxx
Major diameter	D_{ei}	{ xx,xx max. xx,xx min.	Major diameter	D_{ee}	xx,xx tol. h...
Form diameter	D_{Fi}	xx,xx min.	Form diameter	D_{Fe}	xx,xx max.
Minor diameter	D_{ii}	xx,xx + tol. H...	Minor diameter	D_{ie}	{ xx,xx min. xx,xx max.
Base pitch	p_b	xx,xxx	Base pitch	p_b	xx,xxx
Circular space width			Circular tooth thickness		
max. actual	E_{max}	xx,xxx	max. effective	$S_{\text{v max}}$	xx,xxx
min. actual	E_{min}	xx,xxx Ref*	min. effective	$S_{\text{v min}}$	xx,xxx
max. effective	$E_{\text{v max}}$	xx,xxx	max. actual	S_{max}	xx,xxx Ref*
min. effective	$E_{\text{v min}}$	xx,xxx	min. actual	S_{min}	xx,xxx
Measurement between pins	M_{Ri}	xx,xxx-xx,xxx	Measurement over pins	M_{Re}	xx,xxx-xx,xxx
Pin diameter	D_{Ri}	x,xxx	Pin diameter	D_{Re}	xx,xxx
Fillet radius	see table 10		Fillet radius	see table 10	

* Non measurable or values measurable with difficulty used for determination of dimensions to be controlled.

The above drawing data are required for the spline specifications. The standard system is shown; for control alternatives and combinations of types, see 11.4 and 12.2.

The fillet radius permits heavier loading and effects greater fatigue resistance than flat roots, through absence of stress raisers. See section two, tables 44 to 71.

Figure 14 — Fillet root spline — Pressure angle $\alpha_D = 37,5^\circ$ — Modules 0,5 to 10Table 13 — Spline terms, symbols and drawing data, $37,5^\circ$ pressure angle, fillet root side fit

Internal spline			External spline		
Number of teeth	Z	.....	Number of teeth	Z	.....
Module	m	.....	Module	m	.....
Pressure angle	α_D	$37,5^\circ$	Pressure angle	α_D	$37,5^\circ$
Base diameter	D_b	xx,xxxx Ref*	Base diameter	D_b	xx,xxxx
Pitch diameter	D	xx,xxxx Ref*	Pitch diameter	D	xx,xxxx
Major diameter	D_{ei}	{ xx,xx max. xx,xx min.	Major diameter	D_{ee}	xx,xx — tol. h...
Form diameter	D_{Fi}	xx,xx min.	Form diameter	D_{Fe}	xx,xx max.
Minor diameter	D_{ii}	xx,xx + tol. H...	Minor diameter	D_{ie}	{ xx,xx min. xx,xx max.
Base pitch	p_b	xx,xxxx	Base pitch	p_b	xx,xxxx
Circular space width			Circular tooth thickness		
max. actual	$E_{\max}$	xx,xxx	max. effective	$S_v \max$	xx,xxx
min. actual	$E_{\min}$	xx,xxx Ref*	min. effective	$S_v \min$	xx,xxx
max. effective	$E_v \max$	xx,xxx	max. actual	$S_{\max}$	xx,xxx Ref*
min. effective	$E_v \min$	xx,xxx	min. actual	$S_{\min}$	xx,xxx
Measurement between pins	M_{Ri}	xx,xxx-xx,xxx	Measurement over pins	M_{Re}	xx,xxx-xx,xxx
Pin diameter	D_{Ri}	x,xxx	Pin diameter	D_{Re}	xx,xxx
Fillet radius	see table 10		Fillet radius	see table 10	

* Non measurable or values measurable with difficulty used for determination of dimensions to be controlled.

The above drawing data are required for the spline specifications. The standard system is shown; for control alternatives and combinations of types, see 11.4 and 12.2.

The pressure angle and proportions of this spline are a direct compromise of the 30° and 45° pressure angle splines. It is often used on couplings where the external spline is to be cold formed, especially where a 45° pressure angle spline will not satisfy functional requirements and the shaft material is above the hardness limitation of 30° pressure angle cold-forming tools. See section two, tables 72 to 99.

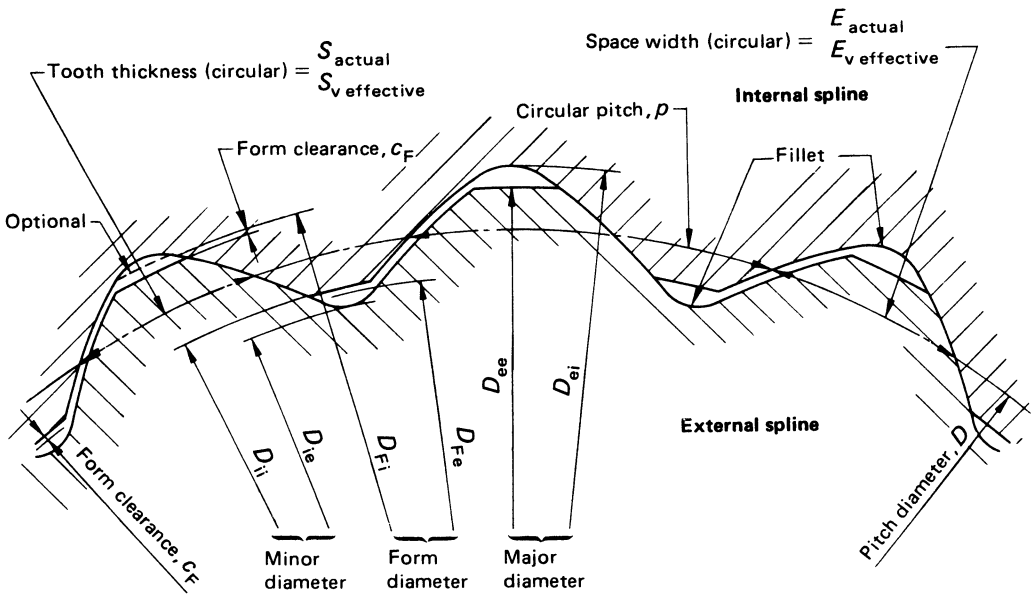


Figure 15 — Fillet root spline — Pressure angle $\alpha_D = 45^\circ$ — Modules 0,25 to 2,5

Table 14 — Spline terms, symbols and drawing data, 45° pressure angle, fillet root side fit

Internal spline			External spline		
Number of teeth	Z	.....	Number of teeth	Z	.....
Module	m	.....	Module	m	.....
Pressure angle	α_D	45°	Pressure angle	α_D	45°
Base diameter	D_b	xx,xxxx Ref*	Base diameter	D_b	xx,xxxx
Pitch diameter	D	xx,xxxx Ref*	Pitch diameter	D	vv,xxxx
Major diameter	D_{ei}	{ xx,xx max. xx,xx min.	Major diameter	D_{ee}	xx,xx — tol. h...
Form diameter	D_{Fi}	xx,xx min.	Form diameter	D_{Fe}	xx,xx max.
Minor diameter	D_{ii}	xx,xx + tol. H...	Minor diameter	D_{ie}	{ xx,xx min. xx,xx max.
Base pitch	p_b	xx,xxxx	Base pitch	p_b	xx,xxxx
Circular space width			Circular tooth thickness		
max. actual	E_{max}	xx,xxx	max. effective	$S_{\text{v max}}$	xx,xxx
min. actual	E_{min}	xx,xxx Ref*	min. effective	$S_{\text{v min}}$	xx,xxx
max. effective	$E_{\text{v max}}$	xx,xxx	max. actual	S_{max}	xx,xxx Ref*
min. effective	$E_{\text{v min}}$	xx,xxx	min. actual	S_{min}	xx,xxx
Measurement between pins	M_{Ri}	xx,xxx-xx,xxx	Measurement over pins	M_{Re}	xx,xxx-xx,xxx
Pin diameter	D_{Ri}	x,xxx	Pin diameter	D_{Re}	xx,xxx
Fillet radius	see table 10		Fillet radius	see table 10	

* Non measurable or values measurable with difficulty used for determination of dimensions to be controlled.

The above drawing data are required for the spline specifications. The standard system is shown; for control alternatives and combinations of types, see 11.4 and 12.2.

Involute splines with 45° pressure angle are used where the toothed member delivers torque only (does not slide under load) and where wall thicknesses are great enough to resist bursting tendencies. The 45° pressure angle spline is highly suitable for cold forming. See section two, tables 100 to 117.

Section two: Dimensions

13 Introduction

The spline tables in this section are based on spline fit class H/h, which gives a minimum effective clearance equal to zero. Selection of a spline fit class having a different deviation allowance requires adjustment to the external spline dimensions (see section one, sub-clause 8.7.2.2).

Tables 15 to 70 give dimensions for 30° pressure angle flat root side fit and fillet root side fit splines for tolerance classes 4, 5, 6 and 7 for spline fit class H/h. Tables 71 to 98 give dimensions for 37,5° pressure angle fillet root side fit splines for tolerance classes 4, 5, 6 and 7 for spline fit class H/h. Tables 99 to 116

give dimensions for 45° pressure angle fillet root side fit splines for tolerance classes 4, 5, 6 and 7 for spline fit class H/h.

14 Dimensions and tolerances

The dimensions and tolerances listed in the tables in this section are derived from the formulae listed in table 2 of section one. Space width and tooth thickness tolerances are based on formulae given in clause 6 and sub-clauses 8.1 and 8.2 of section one.

NOTE — In the following tables a point is used as the decimal marker. (See also the note in sub-clause 3.1 regarding EDP printing of symbols.)

Table 15 — Internal spline

30 degree pressure angle — Side fit — Flat root — Module = 10.00

 E_{vmin} = minimum effective space width, circular = 15.708

Z Number of teeth	D Pitch diameter	D_b Base diameter	D_{ei} Major diameter max.	D_{fi} Major diameter min.	D_{di} Minor diameter min.	$E_{max} = E_{vmin} + (T + \lambda) =$ actual max. space width, circular	4 H	5 H	6 H	7 H
6	60.0000	51.5615	75.44	72.00	54.31	15.772	15.810	15.868	15.964	
7	70.0000	60.6218	85.45	82.00	63.61	15.773	15.812	15.870	15.968	
8	80.0000	69.2820	95.46	92.00	73.11	15.774	15.813	15.873	15.972	
9	90.0000	77.9423	105.46	102.00	82.72	15.775	15.815	15.875	15.975	
10	100.0000	86.6025	115.47	112.00	92.42	15.776	15.816	15.877	15.978	
11	110.0000	95.2628	125.47	122.00	102.18	15.776	15.817	15.879	15.981	
12	120.0000	103.9231	135.48	132.00	111.98	15.777	15.819	15.881	15.984	
13	130.0000	112.5833	145.48	142.00	121.82	15.778	15.820	15.882	15.987	
14	140.0000	121.2436	155.49	152.00	131.68	15.778	15.821	15.884	15.990	
15	150.0000	129.9038	165.49	162.00	141.56	15.779	15.822	15.886	15.992	
16	160.0000	138.5641	175.50	172.00	151.45	15.780	15.823	15.887	15.995	
17	170.0000	147.2243	185.50	182.00	161.36	15.780	15.824	15.889	15.997	
18	180.0000	155.8846	195.51	192.00	171.28	15.781	15.825	15.890	16.000	
19	190.0000	164.5448	205.51	202.00	181.21	15.781	15.826	15.892	16.002	
20	200.0000	173.2051	215.51	212.00	191.15	15.782	15.826	15.893	16.004	
21	210.0000	181.8653	225.52	222.00	201.09	15.783	15.827	15.894	16.006	
22	220.0000	190.5256	235.52	232.00	211.04	15.783	15.828	15.896	16.008	
23	230.0000	199.1859	245.52	242.00	220.99	15.784	15.829	15.897	16.010	
24	240.0000	207.8461	255.53	252.00	230.95	15.785	15.830	15.899	16.012	
25	250.0000	216.5064	265.53	262.00	240.91	15.785	15.830	15.899	16.014	
26	260.0000	225.1666	275.53	272.00	250.87	15.785	15.831	15.901	16.016	
27	270.0000	233.8269	285.54	282.00	260.84	15.785	15.832	15.902	16.018	
28	280.0000	242.4871	295.54	292.00	270.80	15.786	15.833	15.903	16.020	
29	290.0000	251.1474	305.55	302.00	280.78	15.787	15.834	15.904	16.022	
30	300.0000	259.8076	315.55	312.00	290.75	15.787	15.834	15.905	16.023	
31	310.0000	268.4679	325.55	322.00	300.72	15.787	15.835	15.906	16.025	
32	320.0000	277.1281	335.55	332.00	310.70	15.788	15.835	15.907	16.027	
33	330.0000	285.7884	345.55	342.00	320.68	15.788	15.836	15.908	16.028	
34	340.0000	294.4487	355.56	352.00	330.66	15.788	15.837	15.909	16.030	
35	350.0000	303.1089	365.56	362.00	340.64	15.789	15.837	15.910	16.032	
36	360.0000	311.7692	375.56	372.00	350.62	15.789	15.838	15.911	16.033	
37	370.0000	320.4294	385.57	382.00	360.60	15.790	15.839	15.912	16.035	
38	380.0000	329.0897	395.57	392.00	370.59	15.790	15.840	15.913	16.036	
39	390.0000	337.7499	405.57	402.00	380.57	15.790	15.840	15.914	16.038	
40	400.0000	346.4102	415.57	412.00	390.56	15.791	15.841	15.915	16.039	
41	410.0000	355.0704	425.58	422.00	400.54	15.791	15.841	15.916	16.041	
42	420.0000	363.7307	435.58	432.00	410.53	15.792	15.842	15.917	16.042	
43	430.0000	372.3909	445.58	442.00	420.52	15.792	15.842	15.918	16.044	
44	440.0000	381.0512	455.58	452.00	430.50	15.792	15.843	15.919	16.045	
45	450.0000	389.7115	465.59	462.00	440.49	15.793	15.843	15.920	16.047	
46	460.0000	398.3717	475.59	472.00	450.48	15.793	15.844	15.921	16.048	
47	470.0000	407.0320	485.59	482.00	460.47	15.793	15.845	15.922	16.050	
48	480.0000	415.6923	495.59	492.00	470.46	15.794	15.845	15.923	16.052	
49	490.0000	424.3525	505.60	502.00	480.45	15.794	15.846	15.924	16.054	
50	500.0000	433.0127	515.60	512.00	490.44	15.794	15.846	15.924	16.054	
51	510.0000	441.6730	525.60	522.00	500.43	15.795	15.847	15.926	16.056	
52	520.0000	450.3333	535.61	532.00	510.43	15.795	15.847	15.927	16.058	
53	530.0000	458.9935	545.61	542.00	520.42	15.796	15.849	15.928	16.060	
54	540.0000	467.6537	555.61	552.00	530.41	15.796	15.849	15.929	16.061	
55	550.0000	476.3140	565.61	562.00	540.40	15.797	15.850	15.930	16.063	
56	560.0000	484.9743	575.62	572.00	550.39	15.797	15.851	15.931	16.064	
57	570.0000	493.6345	585.62	582.00	560.39	15.797	15.851	15.932	16.066	
58	580.0000	502.2948	595.62	592.00	570.38	15.798	15.852	15.933	16.068	
59	590.0000	510.9550	605.63	602.00	580.37	15.798	15.852	15.934	16.069	
60	600.0000	519.6153	615.63	612.00	590.37	15.799	15.853	15.935	16.071	
61	610.0000	528.2755	625.63	622.00	600.36	15.799	15.854	15.936	16.072	
62	620.0000	536.9358	635.63	632.00	610.36	15.799	15.854	15.937	16.074	
63	630.0000	545.5960	645.64	642.00	620.35	15.800	15.855	15.938	16.076	
64	640.0000	554.2563	655.64	652.00	630.34	15.800	15.856	15.939	16.077	
65	650.0000	562.9165	665.64	662.00	640.34	15.801	15.856	15.940	16.079	
66	660.0000	571.5768	675.65	672.00	650.33	15.801	15.857	15.941	16.080	
67	670.0000	580.2371	685.65	682.00	660.33	15.801	15.858	15.942	16.082	
68	680.0000	588.8973	695.65	692.00	670.32	15.802	15.858	15.943	16.084	
69	690.0000	597.5576	705.65	702.00	680.32	15.802	15.859	15.944	16.085	
70	700.0000	606.2178	715.66	712.00	690.31	15.803	15.859	15.945	16.087	
71	710.0000	614.8781	725.66	722.00	700.31	15.803	15.860	15.946	16.088	
72	720.0000	623.5383	735.66	732.00	710.31	15.803	15.861	15.947	16.090	
73	730.0000	632.1986	745.66	742.00	720.30	15.804	15.861	15.948	16.092	
74	740.0000	640.8588	755.67	752.00	730.30	15.804	15.862	15.949	16.093	
75	750.0000	649.5191	765.67	762.00	740.29	15.805	15.863	15.950	16.095	
76	760.0000	658.1793	775.67	772.00	750.29	15.805	15.863	15.951	16.096	
77	770.0000	666.8396	785.68	782.00	760.28	15.805	15.864	15.952	16.098	
78	780.0000	675.4999	795.68	792.00	770.28	15.806	15.865	15.953	16.100	
79	790.0000	684.1601	805.68	802.00	780.28	15.806	15.865	15.954	16.101	
80	800.0000	692.8204	815.68	812.00	790.27	15.807	15.866	15.955	16.103	
81	810.0000	701.4806	825.69	822.00	800.27	15.807	15.867	15.956	16.104	
82	820.0000	710.1409	835.69	832.00	810.27	15.807	15.867	15.957	16.106	
83	830.0000	718.8011	845.69	842.00	820.26	15.808	15.868	15.958	16.108	
84	840.0000	727.4614	855.69	852.00	830.26	15.808	15.868	15.959	16.109	
85	850.0000	736.1216	865.70	862.00	840.26	15.809	15.869	15.960	16.111	
86	860.0000	744.7819	875.70	872.00	850.25	15.809	15.870	15.961	16.112	
87	870.0000	753.4421	885.70	882.00	860.25	15.809	15.870	15.962	16.114	
88	880.0000	762.1024	895.71	892.00	870.25	15.810	15.871	15.963	16.116	
89	890.0000	770.7627	905.71	902.00	880.25	15.810	15.872	15.964	16.117	
90	900.0000	779.4229	915.71	912.00	890.24	15.811	15.872	15.965	16.119	
91	910.0000	788.0832	925.71	922.00	900.24	15.811	15.873	15.966	16.120	
92	920.0000	796.7434	935.72	932.00	910.24	15.811	15.874	15.967	16.122	
93	930.0000	805.4037	945.72	942.00	920.24	15.812	15.874	15.968	16.124	
94	940.0000	814.0639	955.72	952.00	930.23	15.812	15.875	15.969	16.125	
95	950.0000	822.7242	965.73	962.00	940.23	15.813	15.875	15.970	16.127	
96	960.0000	831.3844	975.73	972.00	950.23	15.813	15.876	15.971	16.128	
97	970.0000	840.0447	985.73	982.00	960.23	15.813	15.877	15.972	16.130	
98	980.0000	848.7049	995.73	992.00	970.22	15.814	15.877	15.973	16.132	
99	990.0000	857.3652	1005.74	1002.00	980.22	15.814	15.878	15.974	16.133	
100	1000.0000	866.0255	1015.74	1012.00	990.22	15.815	15.879	15.975	16.135	

Table 16 — External spline

30 degree pressure angle — Side fit — Flat root — Module = 10.00

 S_{vmax} = maximum effective tooth thickness, circular = 15.708

Z	D	D _b	D _{de}	D _{Fe}	D _{ie}	$S_{min} = S_{vmax} + (T + \lambda) = \text{actual min. tooth thickness, circular}$			
Number of teeth	Pitch diameter	Base diameter	Major diameter max.	Minor diameter min.	Minor diameter min.	4 H	5 H	6 H	7 H
6	60.0000	51.9615	70.00	52.31	44.56	15.644	15.606	15.548	15.452
7	70.0000	60.6218	80.00	61.61	54.55	15.643	15.604	15.546	15.448
8	80.0000	69.2820	90.00	71.11	64.54	15.642	15.603	15.543	15.444
9	90.0000	77.9423	100.00	80.72	74.54	15.641	15.601	15.541	15.441
10	100.0000	86.6025	110.00	90.42	84.53	15.640	15.600	15.539	15.438
11	110.0000	95.2628	120.00	100.18	94.53	15.640	15.599	15.537	15.434
12	120.0000	103.9231	130.00	109.98	104.52	15.639	15.597	15.535	15.432
13	130.0000	112.5833	140.00	119.82	114.52	15.638	15.596	15.533	15.429
14	140.0000	121.2436	150.00	129.68	124.51	15.637	15.595	15.532	15.426
15	150.0000	129.9038	160.00	139.56	134.51	15.637	15.594	15.530	15.423
16	160.0000	138.5641	170.00	149.45	144.50	15.636	15.593	15.529	15.421
17	170.0000	147.2243	180.00	159.36	154.50	15.636	15.592	15.527	15.419
18	180.0000	155.8846	190.00	169.28	164.49	15.635	15.591	15.526	15.416
19	190.0000	164.5448	200.00	179.21	174.49	15.634	15.590	15.524	15.414
20	200.0000	173.2051	210.00	189.15	184.49	15.634	15.590	15.523	15.412
21	210.0000	181.8653	220.00	199.09	194.48	15.633	15.589	15.522	15.410
22	220.0000	190.5256	230.00	209.04	204.48	15.633	15.588	15.520	15.408
23	230.0000	199.1859	240.00	218.99	214.48	15.632	15.587	15.519	15.406
24	240.0000	207.8461	250.00	228.95	224.47	15.632	15.586	15.518	15.404
25	250.0000	216.5064	260.00	238.91	234.47	15.631	15.585	15.517	15.402
26	260.0000	225.1666	270.00	248.87	244.47	15.631	15.585	15.515	15.400
27	270.0000	233.8269	280.00	258.84	254.46	15.630	15.584	15.514	15.398
28	280.0000	242.4871	290.00	268.80	264.46	15.630	15.583	15.513	15.396
29	290.0000	251.1474	300.00	278.78	274.46	15.629	15.582	15.512	15.394
30	300.0000	259.8076	310.00	288.75	284.45	15.629	15.582	15.511	15.393
31	310.0000	268.4679	320.00	298.72	294.45	15.629	15.581	15.510	15.391
32	320.0000	277.1281	330.00	308.70	304.45	15.628	15.580	15.509	15.389
33	330.0000	285.7884	340.00	318.68	314.45	15.628	15.580	15.508	15.388
34	340.0000	294.4487	350.00	328.66	324.44	15.627	15.579	15.507	15.386
35	350.0000	303.1089	360.00	338.64	334.44	15.627	15.578	15.506	15.384
36	360.0000	311.7692	370.00	348.62	344.44	15.627	15.578	15.505	15.383
37	370.0000	320.4294	380.00	358.60	354.43	15.626	15.577	15.504	15.381
38	380.0000	329.0897	390.00	368.59	364.43	15.626	15.577	15.503	15.380
39	390.0000	337.7499	400.00	378.57	374.43	15.625	15.576	15.502	15.378
40	400.0000	346.4102	410.00	388.56	384.43	15.625	15.575	15.501	15.377
41	410.0000	355.0704	420.00	398.54	394.42	15.625	15.575	15.500	15.375
42	420.0000	363.7307	430.00	408.53	404.42	15.624	15.574	15.499	15.374
43	430.0000	372.3909	440.00	418.50	414.42	15.624	15.574	15.498	15.372
44	440.0000	381.0512	450.00	428.49	424.41	15.623	15.573	15.497	15.371
45	450.0000	389.7115	460.00	438.49	434.41	15.623	15.572	15.496	15.369
46	460.0000	398.3717	470.00	448.48	444.41	15.623	15.572	15.495	15.368
47	470.0000	407.0320	480.00	458.47	454.41	15.623	15.571	15.494	15.366
48	480.0000	415.6922	490.00	468.46	464.41	15.622	15.571	15.493	15.365
49	490.0000	424.3525	500.00	478.45	474.40	15.622	15.570	15.492	15.364
50	500.0000	433.0127	510.00	488.44	484.40	15.622	15.570	15.492	15.362
51	510.0000	441.6730	520.00	498.43	494.40	15.621	15.569	15.490	15.360
52	520.0000	450.3332	530.00	508.43	504.39	15.620	15.568	15.489	15.358
53	530.0000	458.9935	540.00	518.42	514.39	15.620	15.567	15.488	15.356
54	540.0000	467.6537	550.00	528.42	524.39	15.619	15.566	15.487	15.355
55	550.0000	476.3140	560.00	538.41	534.39	15.619	15.566	15.486	15.353
56	560.0000	484.9743	570.00	548.39	544.38	15.619	15.565	15.485	15.352
57	570.0000	493.6345	580.00	558.39	554.38	15.618	15.565	15.484	15.350
58	580.0000	502.2948	590.00	568.37	564.37	15.618	15.564	15.483	15.348
59	590.0000	510.9550	600.00	578.37	574.37	15.618	15.563	15.482	15.347
60	600.0000	519.6153	610.00	588.37	584.37	15.617	15.563	15.481	15.345
61	610.0000	528.2755	620.00	598.36	594.37	15.617	15.562	15.480	15.344
62	620.0000	536.9358	630.00	608.36	604.37	15.616	15.562	15.479	15.342
63	630.0000	545.5960	640.00	618.35	614.36	15.616	15.561	15.478	15.340
64	640.0000	554.2563	650.00	628.34	624.36	15.616	15.560	15.477	15.339
65	650.0000	562.9165	660.00	638.34	634.36	15.615	15.560	15.476	15.337
66	660.0000	571.5768	670.00	648.33	644.35	15.615	15.559	15.475	15.336
67	670.0000	580.2371	680.00	658.33	654.35	15.614	15.558	15.474	15.334
68	680.0000	588.8973	690.00	668.32	664.35	15.614	15.558	15.473	15.332
69	690.0000	597.5576	700.00	678.32	674.35	15.614	15.557	15.472	15.331
70	700.0000	606.2178	710.00	688.31	684.34	15.613	15.556	15.471	15.329
71	710.0000	614.8781	720.00	698.31	694.34	15.613	15.556	15.470	15.328
72	720.0000	623.5383	730.00	708.31	704.34	15.612	15.555	15.469	15.326
73	730.0000	632.1986	740.00	718.30	714.33	15.612	15.555	15.468	15.324
74	740.0000	640.8588	750.00	728.30	724.33	15.612	15.554	15.467	15.323
75	750.0000	649.5191	760.00	738.29	734.33	15.611	15.553	15.466	15.321
76	760.0000	658.1793	770.00	748.29	744.33	15.611	15.553	15.465	15.320
77	770.0000	666.8396	780.00	758.28	754.32	15.610	15.552	15.464	15.318
78	780.0000	675.4999	790.00	768.28	764.32	15.610	15.551	15.463	15.316
79	790.0000	684.1601	800.00	778.28	774.32	15.610	15.551	15.462	15.315
80	800.0000	692.8204	810.00	788.27	784.32	15.609	15.550	15.461	15.313
81	810.0000	701.4806	820.00	798.27	794.31	15.609	15.549	15.460	15.312
82	820.0000	710.1409	830.00	808.27	804.31	15.608	15.549	15.459	15.310
83	830.0000	718.8011	840.00	818.26	814.31	15.608	15.548	15.458	15.308
84	840.0000	727.4614	850.00	828.26	824.31	15.608	15.547	15.457	15.307
85	850.0000	736.1216	860.00	838.26	834.30	15.607	15.547	15.456	15.305
86	860.0000	744.7819	870.00	848.25	844.30	15.607	15.546	15.455	15.304
87	870.0000	753.4421	880.00	858.25	854.30	15.606	15.546	15.454	15.302
88	880.0000	762.1024	890.00	868.25	864.29	15.606	15.545	15.453	15.300
89	890.0000	770.7627	900.00	878.25	874.29	15.606	15.544	15.452	15.299
90	900.0000	779.4229	910.00	888.24	884.29	15.605	15.544	15.451	15.297
91	910.0000	788.0832	920.00	898.24	894.29	15.605	15.543	15.450	15.296
92	920.0000	796.7434	930.00	908.24	904.28	15.604	15.542	15.449	15.294
93	930.0000	805.4037	940.00	918.24	914.28	15.604	15.542	15.448	15.292
94	940.0000	814.0639	950.00	928.23	924.28	15.604	15.541	15.447	15.291
95	950.0000	822.7242	960.00	938.23	934.27	15.603	15.540	15.446	15.289
96	960.0000	831.3844	970.00	948.23	944.27	15.603	15.540	15.445	15.288
97	970.0000	840.0447	980.00	958.23	954.27	15.602	15.539	15.444	15.286
98	980.0000	848.7049	990.00	968.22	964.27	15.602	15.539	15.443	15.284
99	990.0000	857.3652	1000.00	978.22	974.26	15.602	15.538	15.442	15.283
100	1000.0000	866.0255	1010.00	988.22	984.26	15.601	15.537	15.441	15.281