Chapter 2: Fits, and Tolerances

2.1 Introduction

Production processes must perform consistently to meet the production and design requirements. In order to achieve this, it is essential to keep the process under control. The permissible level of tolerance depends on the functional requirements, which cannot be compromised. No component can be manufactured precisely to a given dimension; it can only be made to lie between two limits, upper (maximum) and lower (minimum). The difference between the upper and lower limits is termed *permissive tolerance*.

2.2 Principle of interchangeability

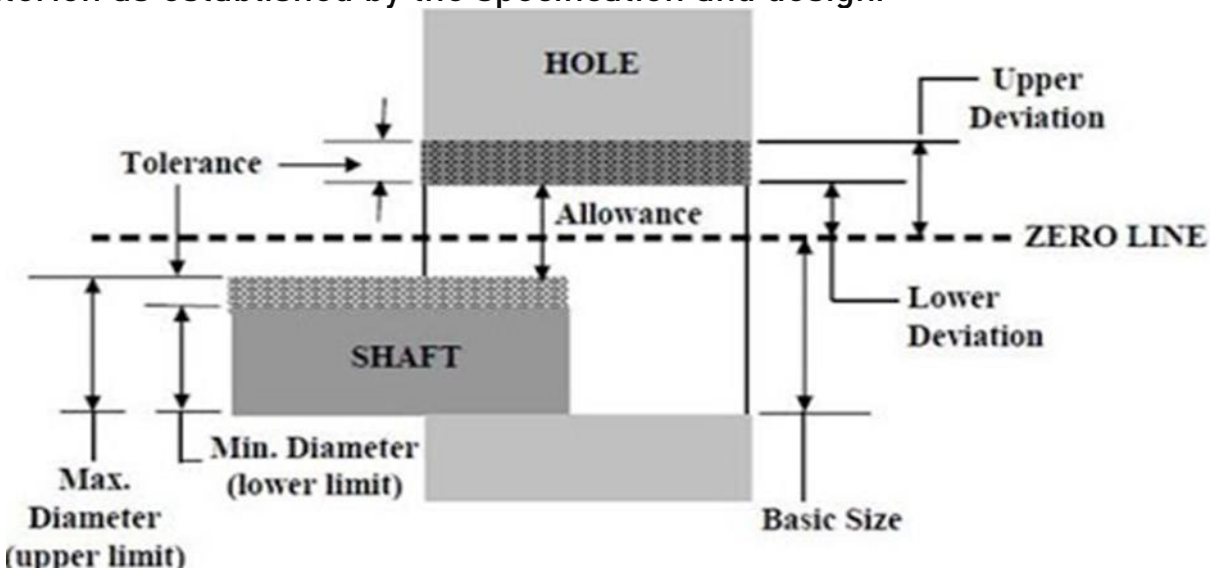
Manufacture of components under such conditions is called *interchangeable manufacture*. When interchangeable manufacture is adopted, any one component selected at random should assemble with any other arbitrarily chosen mating component.

2.2.1 Selective Assembly Approach

In interchangeability of manufacture, minimum clearance should be as small as possible as the assembling of the parts and their proper operating performance under allowable service conditions. The difference between maximum clearance and minimum clearance establishes the sum of the tolerances on companion parts.

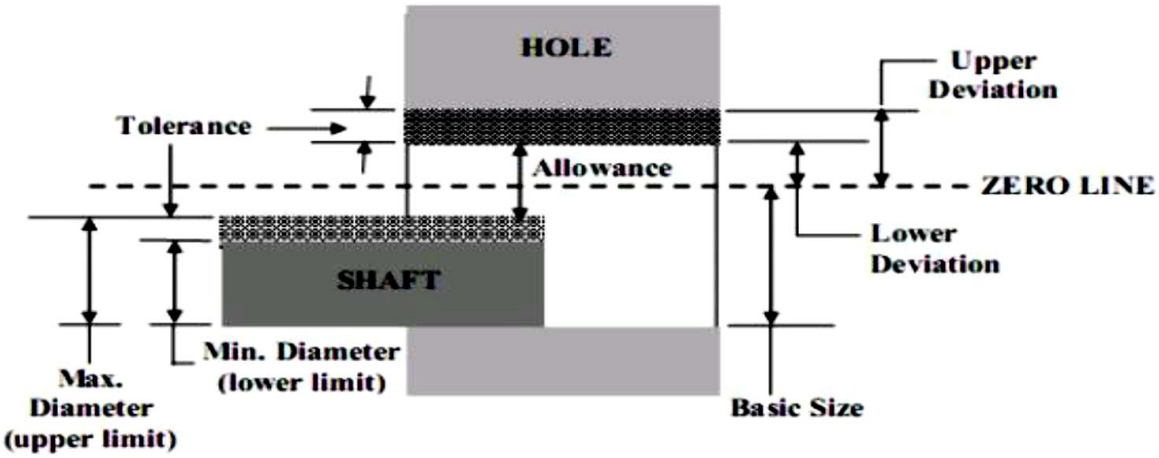
2.3 Tolerances

The basic purpose of providing tolerances is to permit dimensional variations in the manufacture of components, adhering to the performance criterion as established by the specification and design.



2.4 Terminology

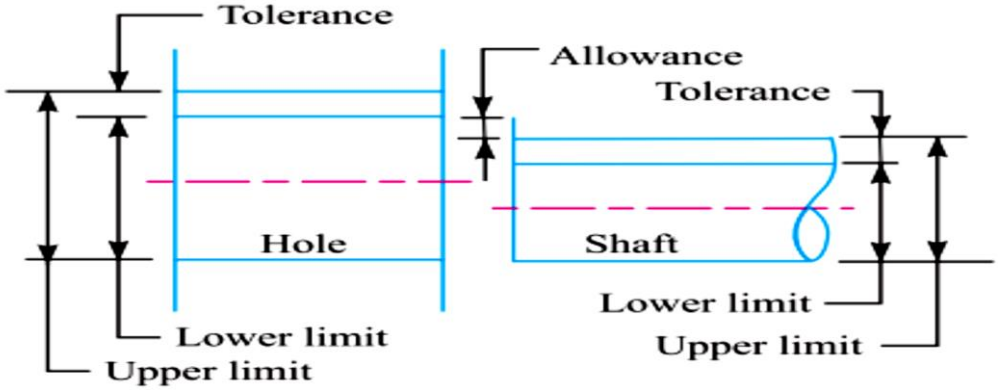
1) NOMINAL SIZE:
   It is the size of a part specified in the drawing.
2) BASIC SIZE:
   It is the size of a part to which all limits of variation are determined. Or it is the theoretical size from which limits of size are derived by the application of allowances and tolerances.
3) ACTUAL SIZE:
   It is the actual measured dimension of a part. Nominal and basic size are often the same.
4) LOWER DEVIATION:
   It is the algebraic difference between the minimum limit of size and the basic size .
5) UPPER DEVIATION:
   It is the algebraic difference between the maximum limit and the basic size.



Interrelationship between tolerances and limits

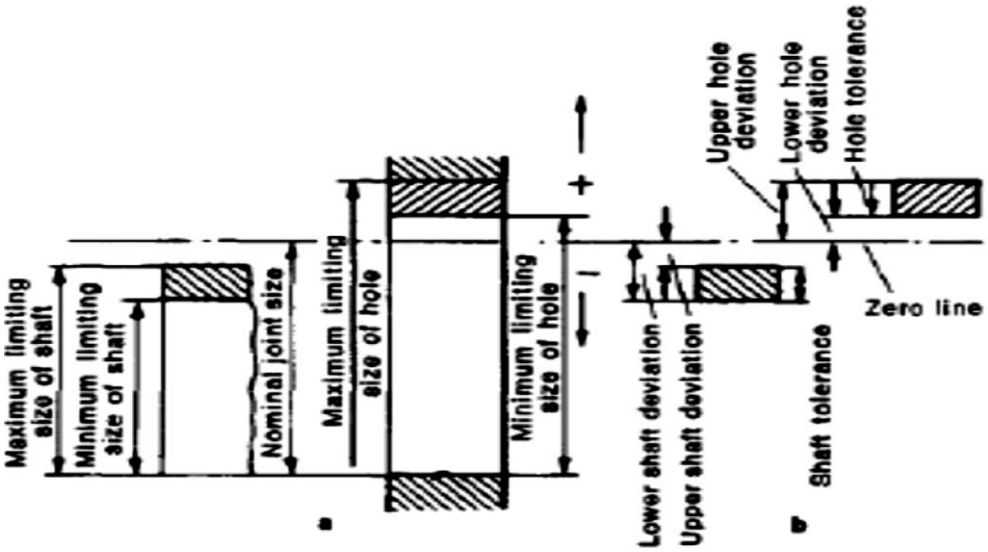
2.5 Limit of Sizes

6) There are two extreme possible sizes of a component.
7) The largest permissible size for a component is called upper limit and smallest size is called lower limit.



2.6 Basis of Limit System

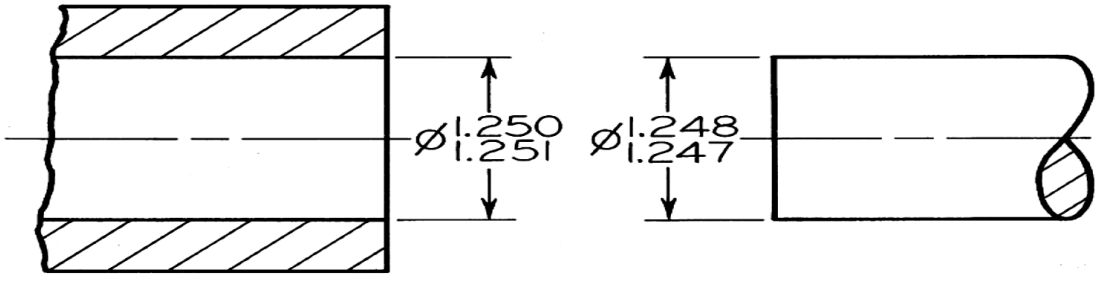
- SHAFT BASIS SYSTEM:
  In this system, the shaft is kept as constant member and different fits are obtained by varying the hole size.
- HOLE BASIS SYSTEM:
  In this system, the hole is kept as a constant member and different fits are obtained by varying the shaft size.
- ZERO LINE
  It is the straight line corresponding to the basic size. The deviations are measured from this line.



2.7 Types of Tolerance

- Tolerance is the total amount that a specific dimension is permitted to vary;
- It is the difference between the maximum and the minimum limits for the dimension.
- For Example a dimension given as 1.625 ± .002 means that the manufactured part may be 1.627" or 1.623", or anywhere between these limit dimensions.

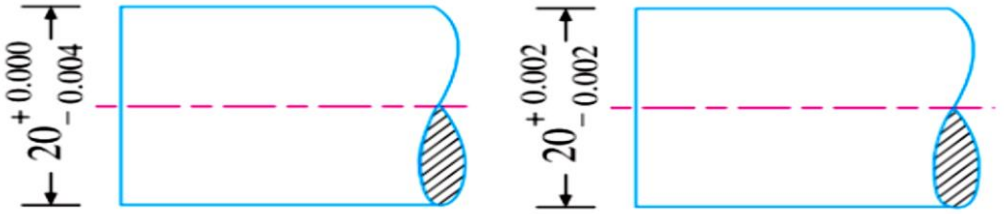
The Tolerance is 0.001"for the Hole as well as for the Shaft



(a) LIMIT DIMENSIONS

2.7.1 Positional Tolerances

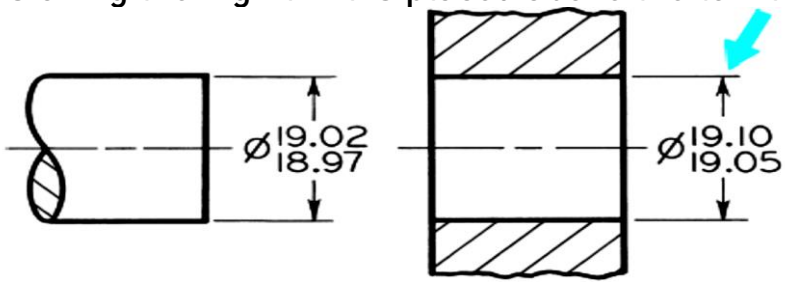
- Two types of positional tolerances are used:
  1. Unilateral tolerances
  2. Bilateral tolerances
- When tolerance is on one side of basic size, it is called unilateral and if it is both in plus and minus then it is known as bilateral tolerance.



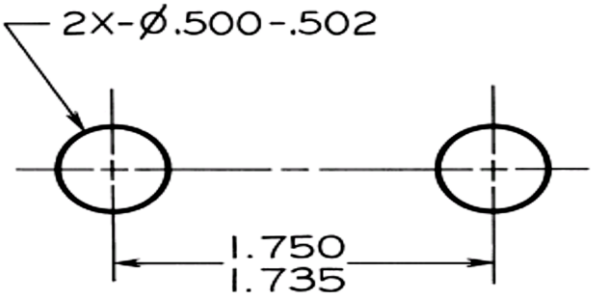
(*a*) Unilateral tolerance (*b*) Bilateral tolerance.

2.7.2 Specifications of Tolerances

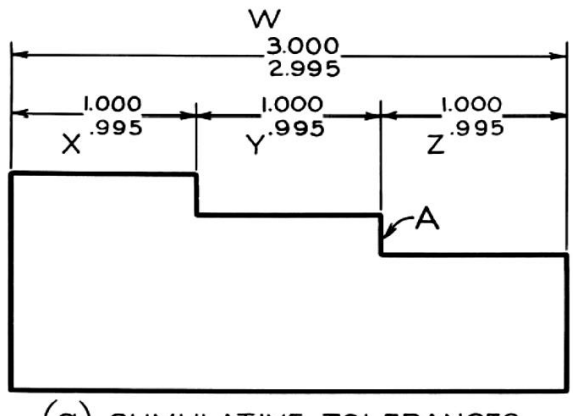
1) Limit Dimensioning the high limit is placed above the low limit.



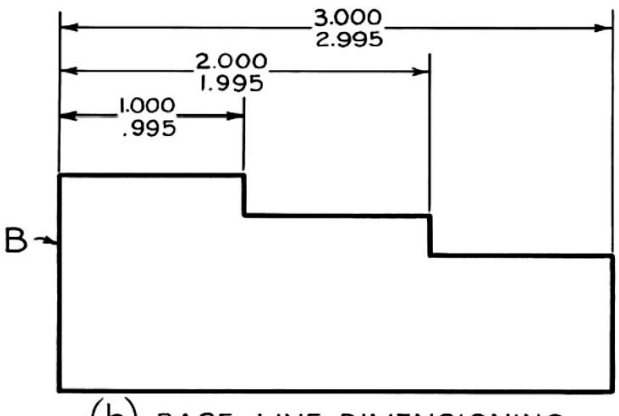
In single-line note form, the low limit precedes the high limit separated by a dash.



2.7.3 Cumulative Tolerances



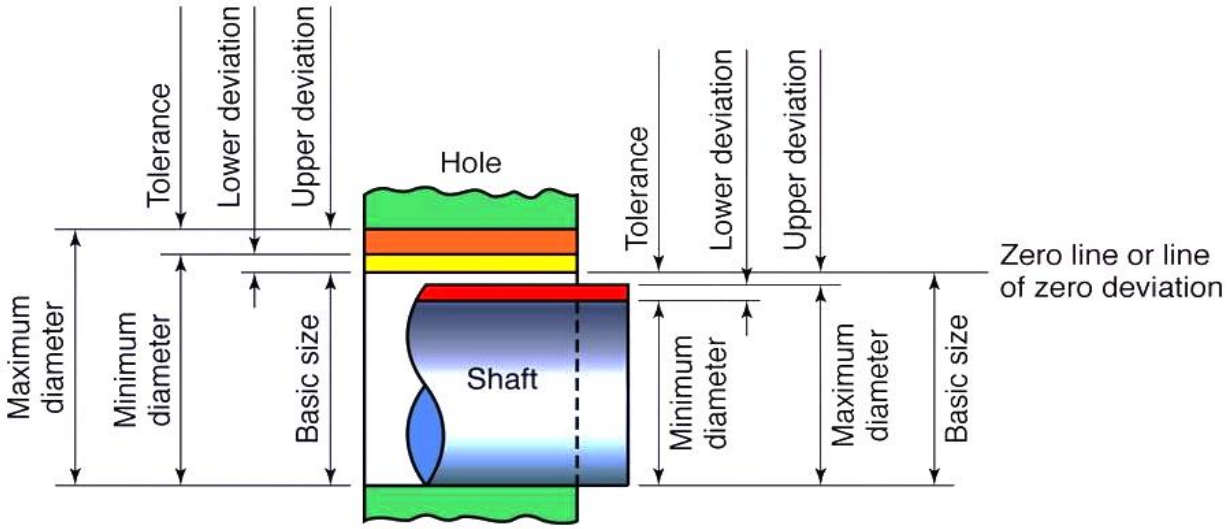
(a) CUMULATIVE TOLERANCES



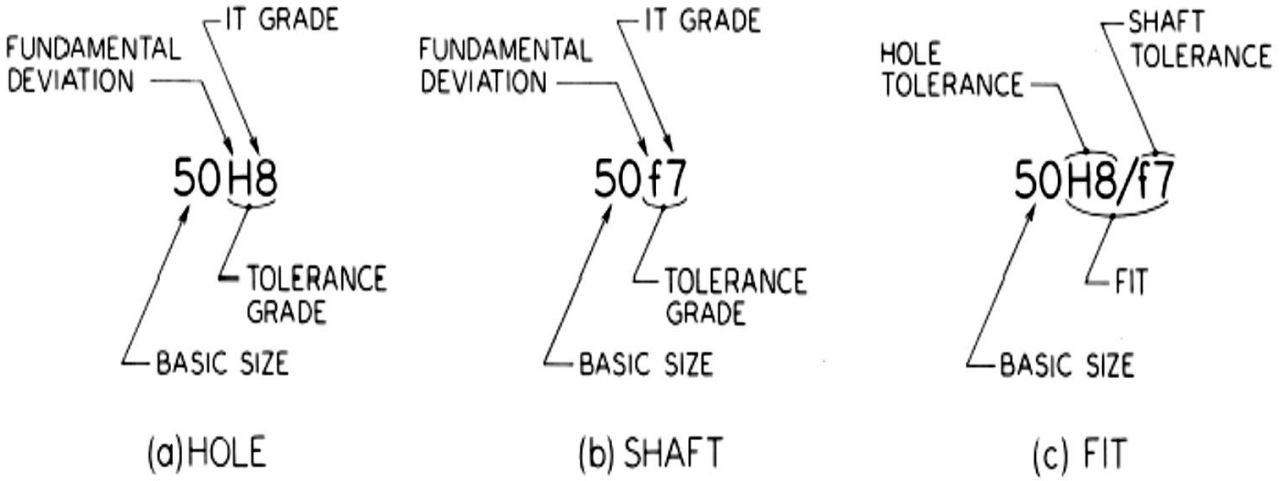
(b) BASE-LINE DIMENSIONING

2.8 International Tolerance Grade (IT)

They are a set of tolerances that varies according to the basic size and



provides a uniform level of accuracy within the grade.



2.9 Specification of Tolerance

The allowable deviation from a standard, e.g.: the range of variation permitted in maintaining a specified dimension in a machined piece.

2.9.1 Some Definitions

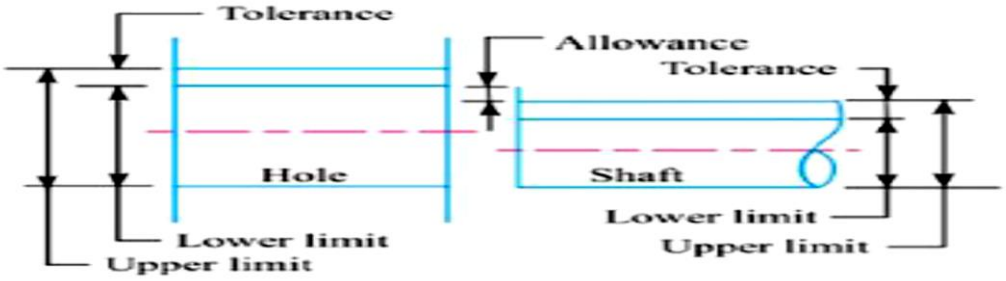
- Basic Size: The size with reference to which the limits of size are fixed.
- Actual Size:
  Actual measured dimension of the part.
- Zero Line:
  It is a straight line corresponding to the basic size. The deviations are measured from this line. The positive and negative deviations are shown above and below the zero line respectively.

2.9.2 Limits of Size

The two extreme permissible sizes of a part between which the actual size should lie.

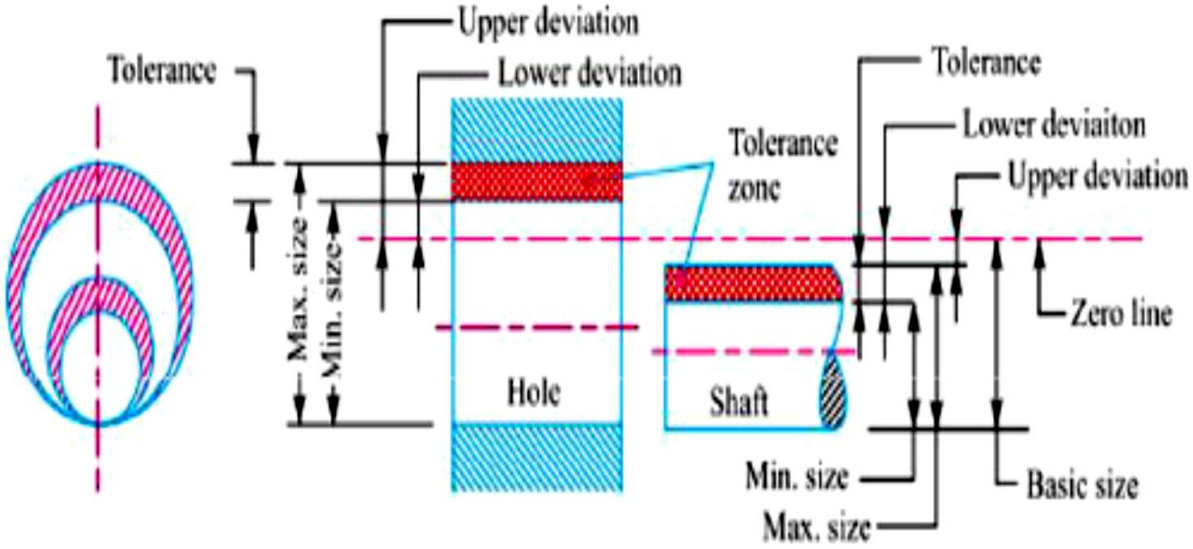
- Maximum Limit of Size:
  The greater of the two limits of size.
- Minimum Limit of Size:
  The smaller of the two limits of size.
- Shaft:
  A term used by convention to designate all external features of a part, including those which are not cylindrical.
- Hole:
  A term used by convention to designate all internal features of a part, including those which are not cylindrical.
- Allowance:
  It is the difference between the basic dimensions of the mating parts. When the shaft size is less than the hole size, then the allowance is positive and when the shaft size is greater than the hole size, then the allowance is negative.

- Tolerance:
  It is the difference between the upper limit and lower limit of a dimension.
- Allowance:
  It is the difference between the basic dimensions of the mating parts. When the shaft size is less than the hole size, then the allowance is positive and when the shaft size is greater than the hole size, then the allowance is negative.
- Tolerance:
  It is the difference between the upper limit and lower limit of a dimension.



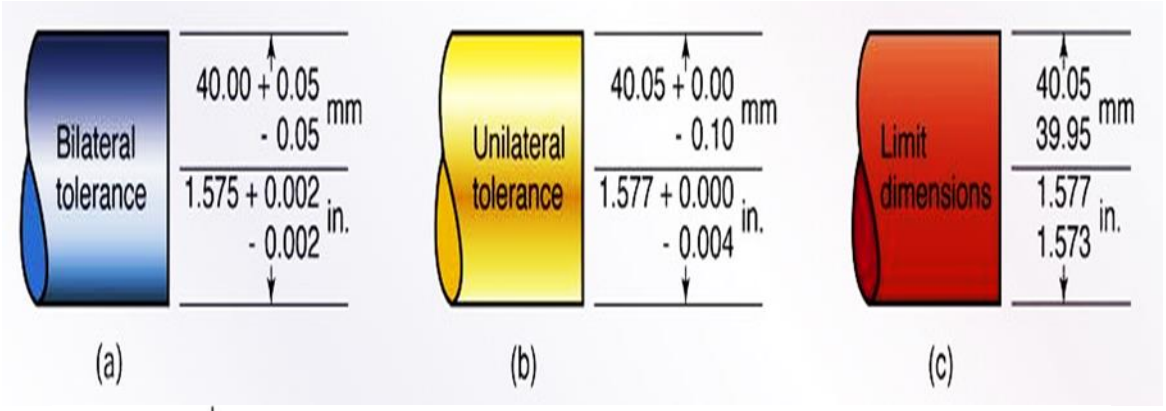
- Tolerance Zone:
  It is the zone between the maximum and minimum limit size.
- Upper Deviation:
  It is the algebraic difference between the maximum size and the basic size. The upper deviation of a hole is represented by a symbol ES (E cart Superior) and of a shaft, it is represented by es.

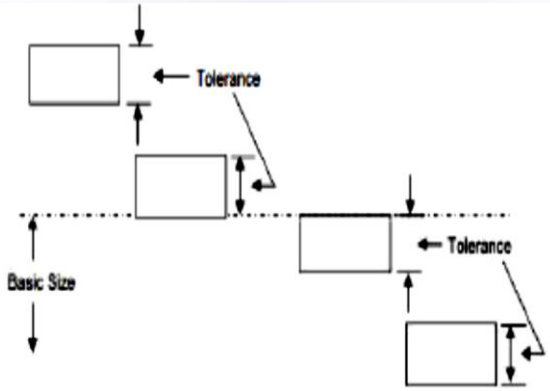
- Lower Deviation:
  It is the algebraic difference between the minimum size and the basic size. The lower deviation of a hole is represented by a symbol EI (Ecart Inferior) and of a shaft, it is represented by ei.

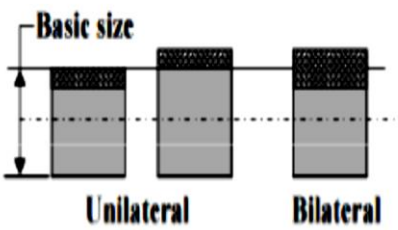


2.9.3 Specification

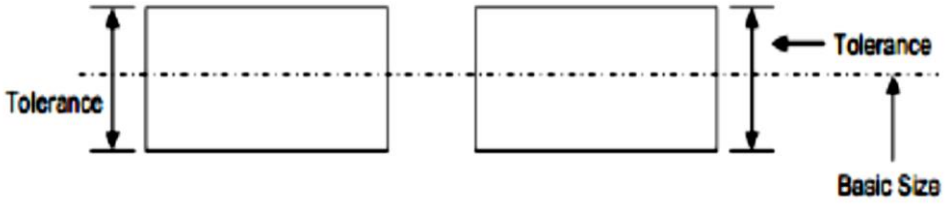
- Unilateral Tolerance
  In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it.







- Bilateral Tolerance
  In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size.

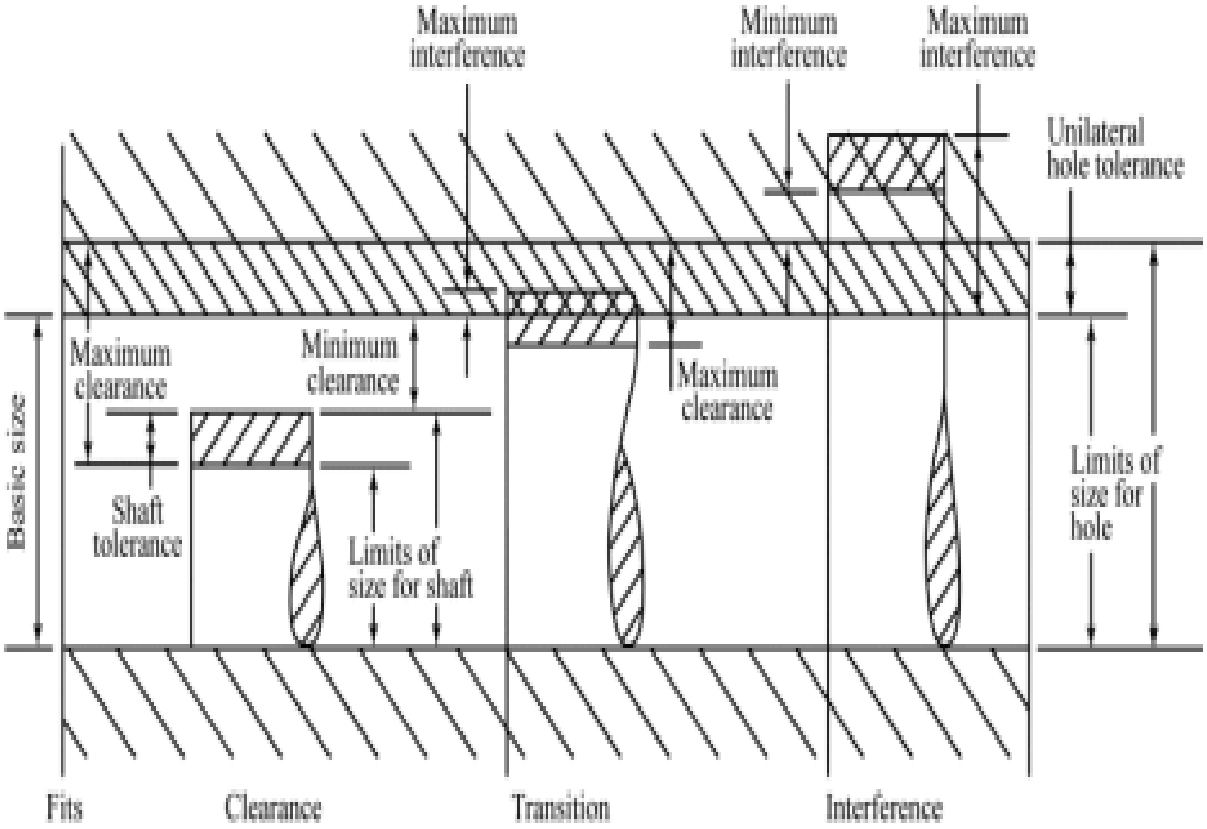


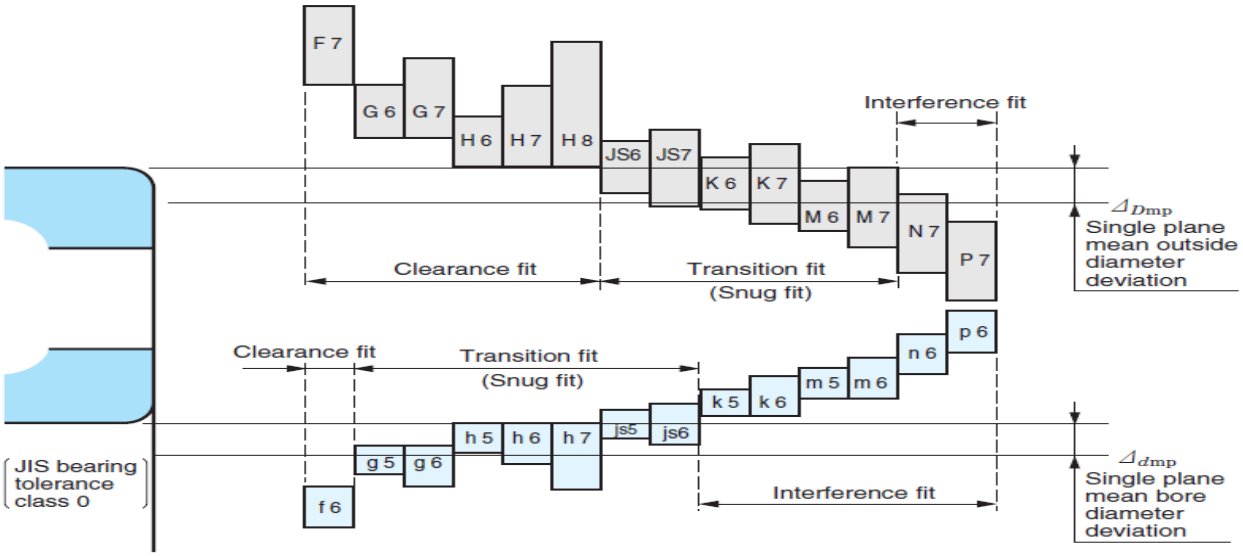
2.10 Fit

Fit is the general term used to signify the range of tightness or looseness that may result from the application of a specific combination of allowances and tolerances in mating parts.

2.10.1 Allowance

An allowance is the intentional difference between the maximum material limits, that is, LLH and HLS (minimum clearance or maximum interference) of the two mating parts. It is the prescribed difference between the dimensions of the mating parts to obtain the desired type of fit. Allowance may be positive or negative. Positive allowance indicates a clearance fit, and an interference fit is indicated by a negative allowance.



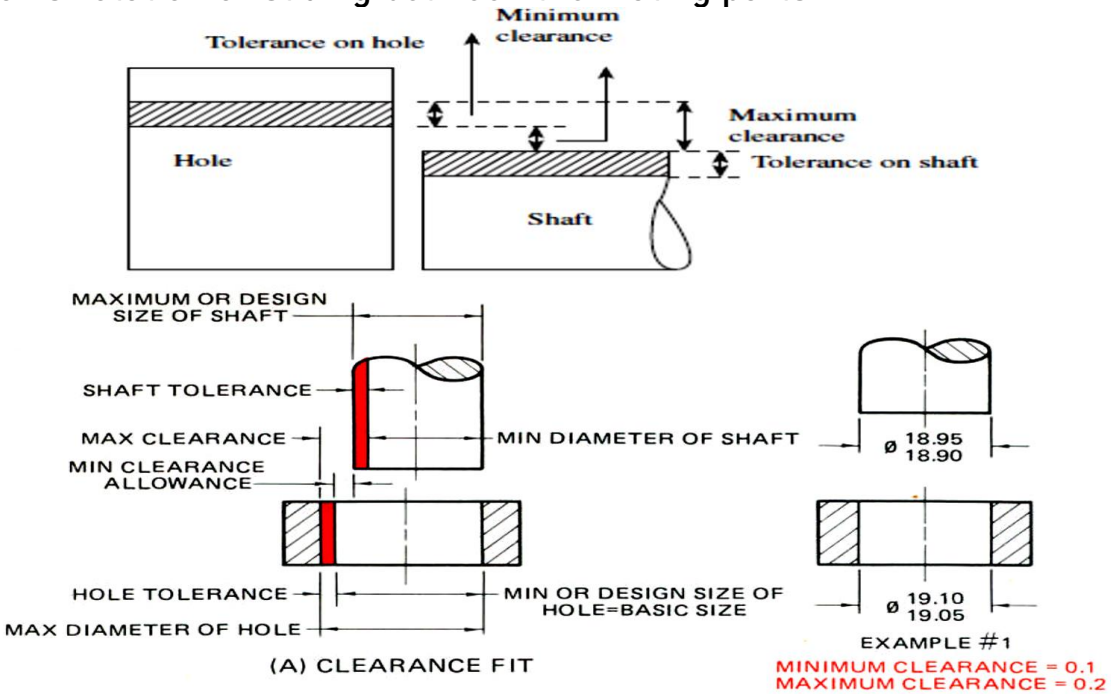


Typical representation of different types of fundamental deviations
(a) Holes (internal features) (b) Shafts (external features)
Examples of different types of fits

2.10.2 Clearance Fit

An internal member fits in an external member (as a shaft in a hole) and always leaves a space or clearance between the parts. Minimum air space is 0.002". This is the allowance and is always positive in a clearance fit.

- In clearance fit, an air space or clearance exists between the shaft and hole.
- Such fits give loose joint.
- A clearance fit has positive allowance, i.e. there is minimum positive clearance between high limit of the shaft and low limit of the hole.
- Allows rotation or sliding between the mating parts.

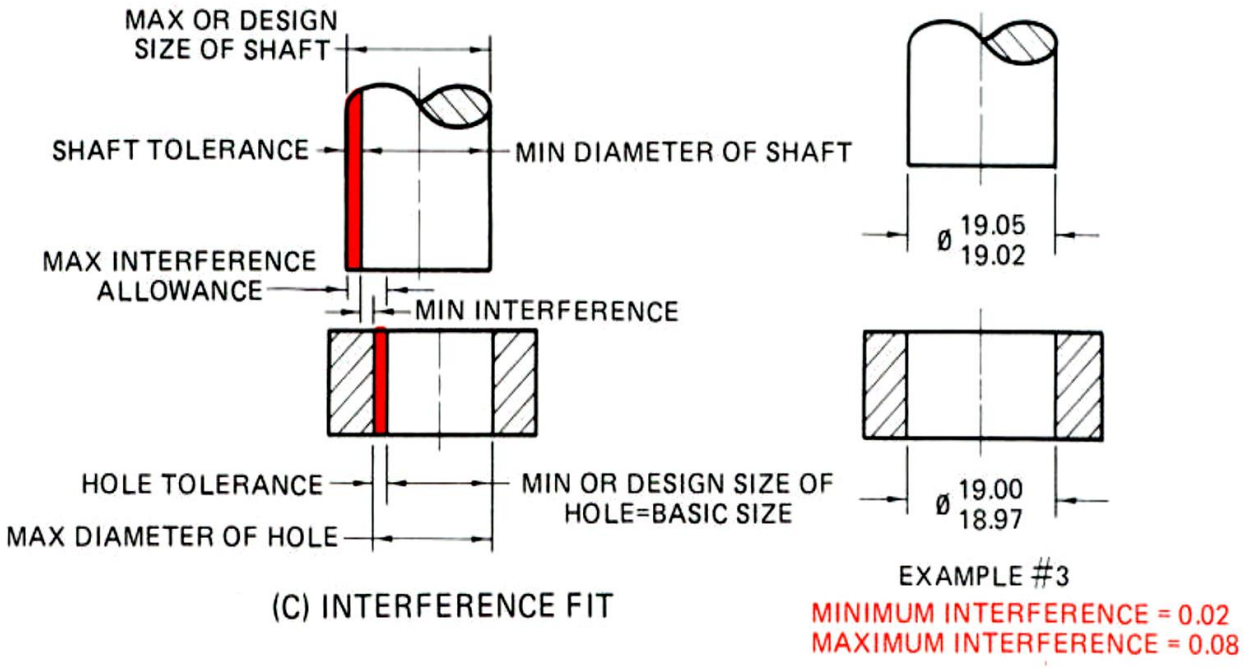


2.10.3 Interference Fit

The internal member is larger than the external member such that there is always an actual interference of material. The smallest shaft is 1.2513" and the largest hole is 1.2506", so that there is an actual interference of metal amounting to at least 0.0007". Under maximum material conditions the interference would be 0.0019". This interference is the allowance, and in an interference fit it is always negative.

- A negative difference between diameter of the hole and the shaft is called interference.
- In such cases, the diameter of the shaft is always larger than the hole diameter.
- It used for components where motion, power has to be transmitted.

Interference exists between the high limit of hole and low limit of the shaft.



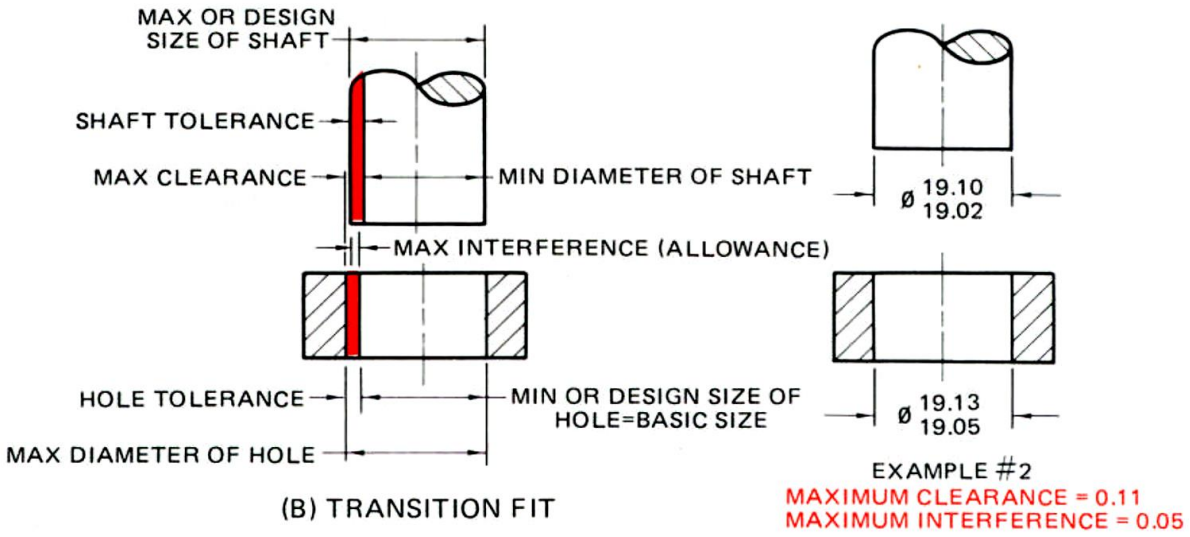
(C) INTERFERENCE FIT

EXAMPLE #3
MINIMUM INTERFERENCE = 0.02
MAXIMUM INTERFERENCE = 0.08

2.10.4 Transition Fit

In this type of fit, the limits for the mating parts are so selected that either a clearance or interference may occurred pending upon the actual size of the mating parts.

- It may result in either clearance fit or interference fit depending on the actual value of the individual tolerances of the mating components.
- Transition fits are a compromise between clearance and interference fits.
- They are used for applications where accurate location is important but either a small amount of clearance or interference is permissible.



2.11 Numerical Examples

Example 2.1 In a limit system, the following limits are specified for a hole and shaft assembly:

Hole = $30^{+0.02}_{+0.00}$ and shaft = $30^{-0.02}_{-0.02}$ –0.05 mm

Determine the (a) tolerance and (b) allowance.

Solution

a) Determination of tolerance:

Tolerance on hole = HLH – LLH = 30.02 – 30.00 = 0.02 mm

Tolerance on shaft = HLS – LLS = [(30 – 0.02) – (30 – 0.05)] = 0.03 mm

b) Determination of allowance:

Allowance = Maximum metal condition of hole – Maximum metal condition of shaft = LLH – HLS = 30.02 – 29.98 = 0.04 mm

Example 2.2 The following limits are specified in a limit system, to give a clearance fit between a hole and a shaft:

Hole = $25^{+0.03}_{-0.00}$ and shaft = $25^{-0,006}_{-0.020}$

Determine the following:

a) Basic size

b) Tolerances on shaft and hole

c) Maximum and minimum clearances.

Solution

a) Basic size is the same for both shaft and hole.

b) Determination of tolerance:

Tolerance on hole = HLH – LLH = 25.03 – 25.00 = 0.03 mm

Tolerance on shaft = HLS – LLS = [(25 – 0.006) – (25 – 0.020)]
= 0.014 mm

Determination of clearances:

Maximum clearance = HLH – LLS = 25.03 – 24.98 = 0.05 mm

Minimum clearance = LLH – HL = 25.00 – (25 – 0.006) = 0.06 mm

Example 2.3 Tolerances for a hole and shaft assembly having a nominal size of 50 mm are as follows:

Hole $= \mathbf{50}^{+0.02}_{+0.02}$ and shaft = $\mathbf{50}^{-0,05}_{-0.08}$

Determine the following:

a) Maximum and minimum clearances
b) Tolerances on shaft and hole
c) Allowance
d) MML of hole and shaft
e) Type of fit.

Solution

a) Determination of clearances:
   Maximum clearance = HLH – LLS = 50.02 – (50 – 0.08) = 0.10 mm
   Minimum clearance = LLH – HLS
   = 50.00 – (50 – 0.005) = 0.05 mm
b) Determination of tolerance:
   Tolerance on hole = HLH – LLH = 50.02 – 50.00 = 0.02 mm
   Tolerance on shaft = HLS – LLS = [(50 – 0.05) – (50 – 0.08)] = 0.03 mm
c) Determination of allowance:
   Allowance = Maximum metal condition of hole – Maximum metal condition of shaft = LLH – HLS = 50.00 – (50 – 0.05) = 0.05 mm
d) Determination of MMLs:
   MML of hole = Lower limit of hole = 50.00 mm
   MML of shaft = Higher limit of shaft = 50.00 – 0.05 = 49.05 mm
e) Since both maximum and minimum clearances are positive, it can be conclude that the given pair has a clearance fit.

Example 2.4 A clearance fit has to be provided for a shaft and bearing assembly having a diameter of 40 mm. Tolerances on hole and shaft are 0.006 and 0.004 mm, respectively. The tolerances are disposed unilaterally. If an allowance of 0.002 mm is provided, find the limits of size for hole and shaft when (a) hole basis system and (b) shaft basis system are used.

Solution

a) When hole basis system is used:
   Hole size:
   HLH = 40.006 mm
   LLH = 40.000 mm
   The allowance provided is +0.002 mm.
   Therefore, HLS = LLH – Allowance = 40.000 – 0.002 = 39.998 mm
   LLS = HLS – Tolerance = 39.998 – 0.004 = 39.994 mm
b) When shaft basis system is used:
   Shaft size:

HLS = 40.000 mm
LLS = 40.000 – 0.004 = 39.996 mm
The allowance provided is +0.002 mm.
Therefore, LLH = HLS + allowance = 40.000 + 0.002 = 40.002 mm
HLH = 40.002 + 0.006 = 40.008 mm
The disposition of tolerance for both hole basis and shaft basis systems are given in Figure.

Example 2.5 For the following hole and shaft assembly, determine (a) hole and shaft tolerance and (b) type of fit.
Hole = $\mathbf{20}^{+0,025}_{+0,000}$ and shaft = $\mathbf{20}^{+0.080}_{+0.005}$

Solution

a) Determination of tolerance:
   Tolerance on hole = HLH – LLH = 20.025 – 20.00 = 0.025 mm
   Tolerance on shaft = HLS – LLS = 20.080 – 20.005 = 0.075 mm
b) To determine the type of fit, calculate maximum and minimum clearances:
   Maximum clearance = HLH – LLS = 20.025 – 20.005 = 0.020 mm
   (Clearance because the difference is positive)
   Minimum clearance = LLH – HLS = 20.00 – 20.080 = –0.08 mm
   (Interference because the difference is negative)
   Since one difference is positive and the other negative, it can be concluded that the given hole and shaft pair has a transition fit.

Example 2.6 For the following hole and shaft assembly, determine (a) hole and shaft tolerance and (b) type of fit
Hole = $\mathbf{20}^{+0.05}_{+0.00}$ and shaft = $\mathbf{20}^{+0.08}_{+0.06}$

Solution

a) Determination of tolerance:
   Tolerance on hole = HLH – LLH = 20.05 – 20.00 = 0.05 mm
   Tolerance on shaft = HLS – LLS = 20.08 – 20.06 = 0.02 mm
b) To determine the type of fit, calculate maximum and minimum clearances:
   Maximum clearance = HLH – LLS = 20.05 – 20.06 = –0.01 mm
   Minimum clearance = LLH – HLS = 20.00 – 20.08 = –0.08 mm
   Since both differences are negative, it can be concluded that the given hole and shaft pair has an interference fit.

❖ The Table gives the Total Tolerance values for ***IT Grades*** from *IT1* to *IT18*:

Basic size mm		International tolerance (IT) grades																
		IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16	IT17	IT18
Above	Up to and in-cluding	Tolerances																
		micrometers											millimeters						
-	3	0.8	1.2	2	3	4	6	10	14	25	40	60	0.1	0.14	0.25	0.4	0.6	1	1.4
3	6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18	0.3	0.48	0.75	1.2	1.8
6	10	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22	0.36	0.58	0.9	1.5	2.2
10	18	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27	0.43	0.7	1.1	1.8	2.7
18	30	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33	0.52	0.84	1.3	2.1	3.3
30	50	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39	0.62	1	1.6	2.5	3.9
50	80	2	3	5	8	13	19	30	46	74	120	190	0.3	0.46	0.74	1.2	1.9	3	4.6
80	120	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54	0.87	1.4	2.2	3.5	5.4
120	180	3.5	5	8	12	18	25	40	63	100	160	250	0.4	0.63	1	1.6	2.5	14	6.3
180	250	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72	1.15	1.85	2.9	4.6	7.2
250	315	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81	1.3	2.1	3.2	5.2	8.1
315	400	7	9	13	18	25	36	57	89	140	230	360	0.57	0.89	1.4	2.3	3.6	5.7	8.9
400	500	8	10	15	20	27	40	63	97	155	250	400	0.63	0.97	1.55	2.5	4	6.3	9.7
500	630	9	11	16	22	32	44	70	110	175	280	440	0.7	1.1	1.75	2.8	4.4	7	11
630	800	10	13	18	25	36	50	80	125	200	320	500	0.8	1.25	2	3.2	5	8	12.5
800	1000	11	15	21	28	40	56	90	140	230	360	560	0.9	1.4	2.3	3.6	5.6	9	14
1000	1250	13	18	24	33	47	66	105	165	260	420	660	1.05	1.65	2.6	4.2	6.6	10.5	16.5
1250	1600	15	21	29	39	55	78	125	195	310	500	780	1.25	1.95	3.1	5	7.8	12.5	19.5
1600	2000	18	25	35	46	65	92	150	230	370	600	920	1.5	2.3	3.7	6	9.2	15	23
2000	2500	22	30	41	55	78	110	175	280	440	700	1100	1.75	2.8	4.4	7	11	17.5	28
2500	3150	26	36	50	68	96	135	210	330	540	860	1350	2.1	3.3	5.4	8.6	13.5	21	33

NOTES:

1. Values for international tolerance grades IT01 and IT0 for basic sizes less than or equal to 500 mm are given in ISO 286-1, annex A, table 5.
2. Values for international tolerance grades IT1 to IT5 (incl) for basic sizes over 500 mm are included for experimental use.
3. International tolerance grades IT14 to IT18 (incl) shall not be used for basic sizes less than or equal to 1 mm.

ANSI RUNNING AND SLIDING FITS (Basic-Hole System)

Values shown below are in thousandths of an inch

Nominal Size Range (in)		Class RC1			Class RC2			Class RC3			Class RC4			Class RC5		
		Clearance	Standard Limits		Clearance	Standard Limits		Clearance	Standard Limits		Clearance	Standard Limits		Clearance	Standard Limits	
			Hole	Shaft		Hole	Shaft		Hole	Shaft		Hole	Shaft		Hole	Shaft
Over	To		H5	g4		H6	g5		H7	f6		H8	f7		H8	e7
0	0,12	0,1	+0.2	-0.1	0,1	+0.25	-0.1	0,3	+0.4	-0.3	0,3	+0.6	-0.3	0.6	+0.6	-0.6
		0,45	0	-0.25	0,55	0	-0.3	0,95	0	-0.55	1,3	0	-0.7	1.6	-0	-1.0
0,12	0,24	0,15	+0.2	-0.15	0,15	+0.3	-0.15	0,4	+0.5	-0.4	0,4	+0.7	-0.4	0.8	+0.7	-0.8
		0,5	0	-0.3	0,65	0	-0.35	1,12	0	-0.7	1,6	0	-0.9	2.0	-0	-1.3
0,24	0,4	0,2	0.25	-0.2	0,2	+0.4	-0.2	0,5	+0.6	-0.5	0,5	+0.9	-0.5	1.0	+0.9	-1.0
		0,6	0	-0.35	0,85	0	-0.45	1,5	0	-0.9	2	0	-1.1	2.5	-0	-1.6
0,4	0,71	0,25	+0.3	-0.25	0,25	+0.4	-0.25	0,6	+0.7	-0.6	0,6	+1.0	-0.6	1.2	+1.0	-1.2
		0,75	0	-0.45	0,95	0	-0.55	1,7	0	-1.0	2,3	0	-1.3	2.9	-0	-1.9
0,71	1,19	0,3	+0.4	-0.3	0,3	+0.5	-0.3	0,8	+0.8	-0.8	0,8	+1.2	-0.8	1.6	+1.2	-1.6
		0,95	0	-0.55	1,2	0	-0.7	2,1	0	-1.3	2,8	0	-1.6	3.6	-0	-2.4
1,19	1,97	0,4	+0.4	-0.4	0,4	+0.6	-0.4	1	+1.0	-1.0	1.0	+1.6	-1.0	2.0	+1.6	-2.0
		1,1	0	-0.7	1,4	0	-0.8	2,6	0	-1.6	3,6	0	-2.0	4.6	-0	-3.0
1,97	3,15	0,4	+0.5	-0.4	0,4	+0.7	-0.4	1,2	+1.2	-1.2	1,2	+1.8	-1.2	2.5	+1.8	-2.5
		1,2	0	-0.7	1,6	0	-0.9	3,1	0	-1.9	4,2	0	-2.4	5.5	-0	-3.7
3,15	4,73	0,5	+0.6	-0.5	0,5	+0.9	-0.5	1,4	+1.4	-1.4	1,4	+2.2	-1.4	3.0	+2.2	-3.0
		1,5	0	-0.9	2.0	0	-1.1	3,7	0	-2.3	5	0	-2.8	6.6	-0	-4.4
4,73	7,09	0,6	+0.7	-0.6	0,6	+1.0	-0.6	1,6	+1.6	-1.6	1,6	+2.5	-1.6	3.5	+2.5	-3.5
		1,8	0	-1.1	2,3	0	-1.3	4,2	0	-2.6	5,7	0	-3.2	7.6	-0	-5.1
7,09	9,85	0,6	+0.8	-0.6	0,6	+1.2	-0.6	2	+1.8	-2.0	2	+2.8	-2.0	4.0	+2.8	-4.0
		2	0	-1.2	2,6	0	-1.4	5	0	-3.2	6,6	0	-3.8	8.6	-0	-5.8
9,85	12,41	0,8	+0.9	-0.8	0,8	+1.2	-0.8	2.5	+2.0	-2.5	2,5	+3.0	-2.5	5.0	+3.0	-5.0
		2,3	0	-1.4	2,9	0	-1.7	5,7	0	-3.7	7,5	0	-4.5	10.0	0	-7.0
12,41	15,75	1	+1.0	-1.0	1	+1.4	-1.0	3	+2.2	-3.0	3	+3.5	-3.0	6.0	+3.5	-6.0
		2,7	0	-1.7	3,4	0	-2.0	6,6	0	-4.4	8,7	0	-5.2	11.7	0	-8.2
15,75	19,69	1,2	+1.0	-1.2	1,2	+1.6	-1.2	4	+1.6	-4.0	4	+4.0	-4.0	8.0	+4.0	-8.0
		3	0	-2.0	3,8	0	-2.2	8,1	0	-5.6	10,5	0	-6.5	14.5	0	-10.5
19,69	30,09	1,6	+1.2	-1.6	1,6	+2.0	-1.6	5	+3.0	-5.0	5	+5.0	-5.0	10.0	+5.0	-10.0
		3,7	0	-2.5	4,8	0	-2.8	10	0	-7.0	13	0	-8.0	18.0	0	-13.0
30,09	41,49	2	+1.6	-2.0	2	+2.5	-2.0	6	+4.0	-6.0	6	+6.0	-6.0	12.0	+6.0	-12.0
		4,6	0	-3.0	6,1	0	-3.6	12,5	0	-8.5	16	0	-10.0	22.0	0	-16.0
41,49	56,19	2,5	+2.0	-2.5	2,5	+3.0	-2.5	8	+5.0	-8.0	8	+8.0	-8.0	16.0	+8.0	-16.0
		5,7	0	-3.7	7,5	0	-4.5	16	0	-11.0	21	0	-13.0	29.0	0	-21.0
56,19	76,39	3	+2.5	-3.0	3	+4.0	-3.0	10	+6.0	-10.0	10	+10.0	-10.0	20.0	+10.0	-20.0
		7,1	0	-4.6	9,5	0	-5.5	20	0	-14.0	26	0	-16.0	36.0	0	-26.0
76,39	100,9	4	+3.0	-4.0	4	+5.0	-4.0	12	+8.0	-12.0	12	+12.0	-12.0	25.0	+12.0	-25.0
		9	0	-6.0	12	0	-7.0	25	0	-17.0	32	0	-20.0	45.0	0	-33.0

ISO Tolerances for Holes (ISO 286-2)

Nominal hole sizes (mm)

over	3	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225	250	280	315	355
inc.	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225	250	280	315	355	400

micrometres

E6	+28 +20	+34 +25	+43 +32	+53 +40	+66 +50	+79 +60	+94 +72	+110 +85	+129 +100	+142 +110	+161 +125									
E7	+32 +20	+40 +25	+50 +32	+61 +40	+75 +50	+90 +60	+107 +72	+125 +85	+146 +100	+162 +110	+185 +125									
E11	+95 +20	+115 +25	+142 +32	+170 +40	+210 +50	+250 +60	+292 +72	+335 +85	+390 +100	+430 +110	+485 +125									
E12	+140 +20	+175 +25	+212 +32	+250 +40	+300 +50	+360 +60	+422 +72	+485 +85	+560 +100	+630 +110	+695 +125									
E13	+200 +20	+245 +25	+302 +32	+370 +40	+440 +50	+520 +60	+612 +72	+715 +85	+820 +100	+920 +110	+1 015 +125									
F6	+18 +10	+22 +13	+27 +16	+33 +20	+41 +2	+49 +30	+58 +36	+68 43	+79 +50	+88 +56	+98 +62									
F7	+22 +10	+28 +13	+34 +16	+41 +20	+50 +25	+60 +30	+71 +36	+83 43	+96 +50	+108 +56	+119 +62									
F8	+28 +10	+35 +13	+43 +16	+53 +20	+64 +25	+76 +30	+90 +36	+106 43	+122 +50	+137 +56	+151 +62									
G6	+12 +4	+14 +5	+17 +6	+20 +7	+25 +9	+29 +10	+34 +12	+39 +14	+44 +15	+49 +17	+54 +18									
G7	+16 +4	+20 +5	+24 +6	+28 +7	+34 +9	+40 +10	+47 +12	+54 +14	+61 +15	+69 +17	+75 +18									
G8	+22 +4	+27 +5	+33 +6	+40 +7	+48 +9	+56 +10	+66 +12	+77 +14	+87 +15	+98 +17	+107 +18									
H6	+8 0	+9 0	+11 0	+13 0	+16 0	+19 0	+22 0	+25 0	+29 0	+32 0	+36 0									
H7	+12 0	+15 0	+18 0	+21 0	+25 0	+30 0	+35 0	+40 0	+46 0	+52 0	+57 0									
H8	+18 0	+22 0	+27 0	+33 0	+39 0	+46 0	+54 0	+63 0	+72 0	+81 0	+89 0									
H9	+30 0	+36 0	+43 0	+52 0	+62 0	+74 0	+87 0	+100 0	+115 0	+130 0	+140 0									
H10	+48 0	+58 0	+70 0	+84 0	+100 0	+120 0	+140 0	+160 0	+185 0	+210 0	+230 0									
H11	+75 0	+90 0	+110 0	+130 0	+160 0	+190 0	+220 0	+250 0	+290 0	+320 0	+360 0									
J6	+5 -3	+5 -4	+6 -5	+8 -5	+10 -6	+13 -6	+16 -6	+18 -7	+22 -7	+25 -7	+29 -7									
J7	+6 -6	+8 -7	+10 -8	+12 -9	+14 -11	+18 -12	+22 -13	+26 -14	+30 -16	+36 -16	+39 -18									
J8	+10 -8	+12 -10	+15 -12	+20 -13	+24 -15	+28 -18	+34 -20	+41 -22	+47 -25	+55 -26	+60 -29									