

2.6 Tolerances, limits and fits.

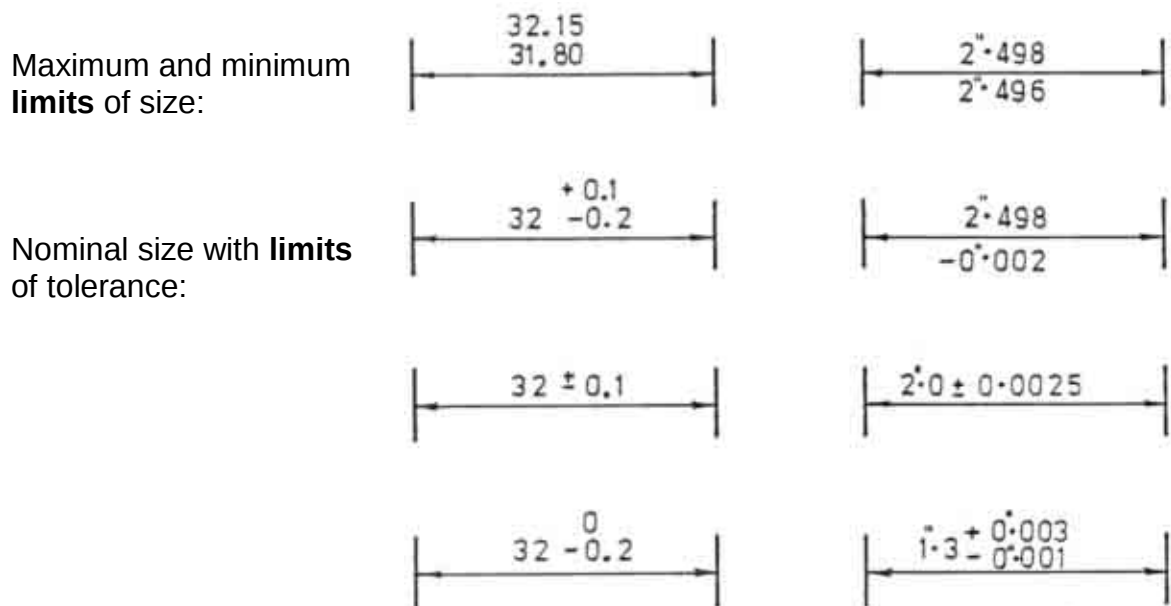
In order to ensure that assemblies function properly their component parts must **fit together** in a predictable way. As mentioned in section 2.5, no component can be manufactured to an exact size, so the designer has to decide on appropriate upper and lower limits for each dimension.



Accurately toleranced dimensioned features usually take much more time to manufacture correctly and therefore can increase production costs significantly. Good engineering practise finds the optimum balance between required accuracy for the function of the component and minimum cost of manufacture.

2.6.1 Dimension tolerances.

If a dimension is specified, in millimeters, as 10 ± 0.02 , the part will be acceptable if the dimension is manufactured to an actual size between 9.98 and 10.02 mm. Below are some examples of ways of defining such limits for a linear dimension.



To give you a feel for the magnitude of decimal values in mm, consider these facts:

The thickness of the paper this page is printed on is approximately **0.100 mm**.

Average human hair thickness is approximately **0.070 mm**.

The human eye cannot resolve a gap between two points smaller than about **0.020mm**, at a 20cm distance.

If you raise the temperature of a 100mm long block of steel by 10°C it will increase in length by approximately **0.020mm**.

2.6.2 General tolerancing.

General tolerance notes apply tolerances to all unspecified dimensions on a drawing. They can save time and help to make a drawing less cluttered. Examples are shown below in Figure xx.

TOLERANCE EXCEPT WHERE
OTHERWISE STATED ± 0.5

SIZE		TOLERANCE
—	UP TO X	± 0.1
OVER X	UP TO XX	± 0.25
OVER XX	UP TO XXX	± 1
OVER XXX	—	± 2
ON ANGLES		$\pm 0.5^\circ$

TOLERANCE ON CAST THICKNESSES
 $\pm 1\%$

FOR TOLERANCES ON FORGING
DIMENSIONS SEE BS 4114

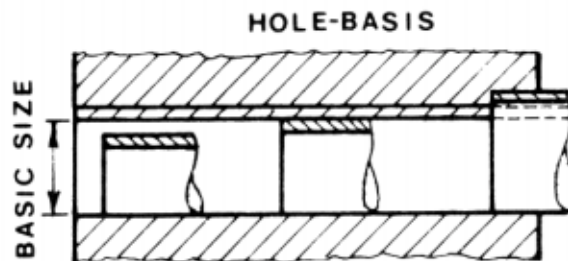
Figure xx. Some examples of general tolerance notes.

2.6.3 Limits and fits for shafts and holes.

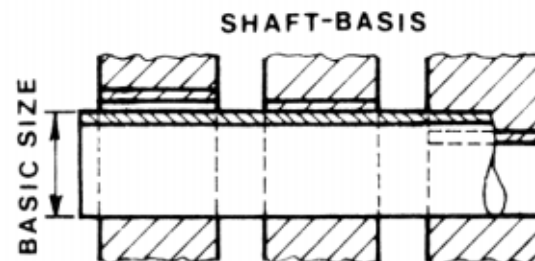
2.6.3.1 Basic size and shaft/hole tolerancing systems.

The **basic size** or **nominal size** is the size of shaft or hole that the designer specifies before applying the limits to it. There are two systems used for specifying shaft/hole tolerances:

Basic hole system: Starts with the basic hole size and adjusts shaft size to fit.



Basic shaft system: Starts with the basic shaft size and adjusts hole size to fit.



Because holes are usually made with standard tools such as drills and reamers, etc, the **basic hole system** tends to be preferred and will therefore be used here

2.6.3.2 Fit.

The **fit** represents the tightness or looseness resulting from the application of tolerances to mating parts, e.g. shafts and holes. Fits are generally classified as one of the following:

- Clearance fit:** Assemble/disassemble by hand.
Creates **running & sliding assemblies**, ranging from loose low cost, to free-running high temperature change applications and accurate minimal play locations.
- Transition fit:** Assembly usually requires press tooling or mechanical assistance of some kind.
Creates **close accuracy** with little or no interference.
- Interference fit:** Parts need to be forced or shrunk fitted together.
Creates **permanent assemblies** that retain and locate themselves.

2.6.3.3 ISO limits and fits.

Fits have been standardised and can be taken directly from those tabulated in the BS 4500 standard, '**ISO limits and fits.**'

The BS 4500 standard refers to tolerance symbols made up with a letter followed by a number. The BS Data Sheet BS 4500A, as shown on the following two pages, shows a range of fits derived, using the hole basis, from the following tolerances:

Holes: **H11 H9 H8 H7**

Shafts: **c11 d10 e9 f7 g6 k6 n6 p6 s6**

Remember:

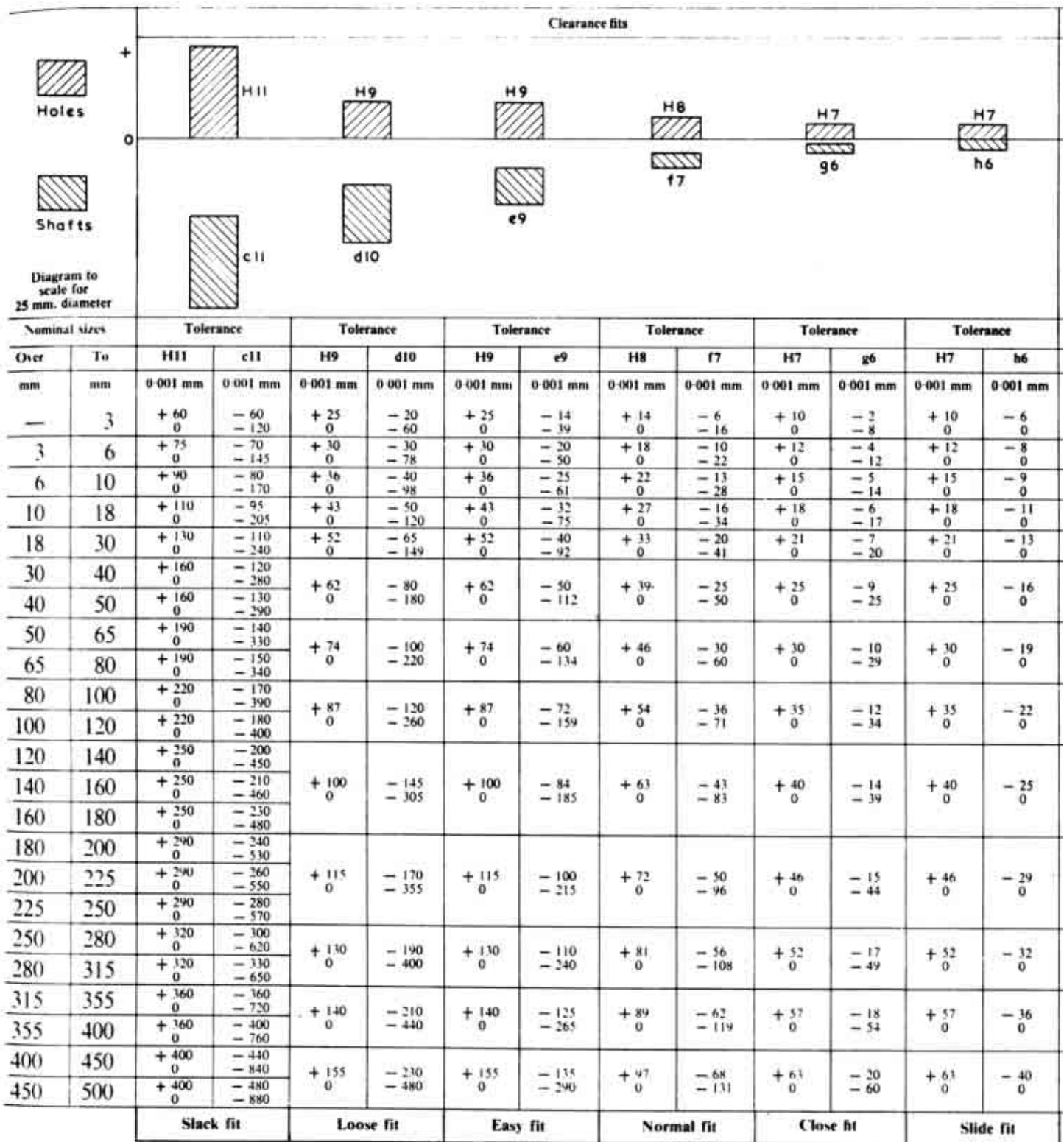
- Capital letters always refer to holes, lower case always refer to shafts.
- The greater the number the greater or wider the tolerances.

The selection of a pair of these tolerances will give you the fit. The number of possible combinations is huge. BS 4500 helps to standardise this and offers a range of fits suitable for most engineering applications.

Examine an extract from the BS 4500 data sheet on page 4 & 5 and you will observe the general class of fit specified on the top row. A more detailed description of the fit is given on the bottom row.

See the table in section 2.6.4 for guidance on the selection of types of fit.

Selected ISO Fits - Hole Basis. Extract from BS 4500, data Sheet 4500A.



Selected ISO Fits - Hole Basis. Extract from BS 4500, data Sheet 4500A.

Transition fits				Interference fits				 Holes  Shafts	
 H7	 k6	 H7	 n6	 H7	 p6	 H7	 s6		
Tolerance		Tolerance		Tolerance		Tolerance		Nominal sizes	
H7	k6	H7	n6	H7	p6	H7	s6	Over	To
0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	mm	mm
+ 10 0	+ 6 + 0	+ 10 0	+ 10 + 4	+ 10 0	+ 12 + 6	+ 10 0	+ 20 + 14	—	3
+ 12 0	+ 9 + 1	+ 12 0	+ 16 + 8	+ 12 0	+ 20 + 12	+ 12 0	+ 27 + 19	3	6
+ 15 0	+ 10 + 1	+ 15 0	+ 19 + 10	+ 15 0	+ 24 + 15	+ 15 0	+ 32 + 23	6	10
+ 18 0	+ 12 + 1	+ 18 0	+ 23 + 12	+ 18 0	+ 29 + 18	+ 18 0	+ 39 + 28	10	18
+ 21 0	+ 15 + 2	+ 21 0	+ 28 + 15	+ 21 0	+ 35 + 22	+ 21 0	+ 48 + 35	18	30
+ 25 0	+ 18 + 2	+ 25 0	+ 33 + 17	+ 25 0	+ 42 + 26	+ 25 0	+ 59 + 43	30	40
								40	50
+ 30 0	+ 21 + 2	+ 30 0	+ 39 + 20	+ 30 0	+ 51 + 32	+ 30 0	+ 72 + 53	50	65
						+ 30 0	+ 78 + 59	65	80
+ 35 0	+ 25 + 3	+ 35 0	+ 45 + 23	+ 35 0	+ 59 + 37	+ 35 0	+ 93 + 71	80	100
						+ 35 0	+ 101 + 79	100	120
+ 40 0	+ 28 + 3	+ 40 0	+ 52 + 27	+ 40 0	+ 68 + 43	+ 40 0	+ 117 + 92	120	140
						+ 40 0	+ 125 + 100	140	160
						+ 40 0	+ 133 + 108	160	180
+ 46 0	+ 33 + 4	+ 46 0	+ 60 + 31	+ 46 0	+ 79 + 50	+ 46 0	+ 151 + 122	180	200
						+ 46 0	+ 159 + 130	200	225
						+ 46 0	+ 169 + 140	225	250
+ 52 0	+ 36 + 4	+ 52 0	+ 66 + 34	+ 52 0	+ 88 + 56	+ 52 0	+ 190 + 158	250	280
						+ 52 0	+ 202 + 170	280	315
+ 57 0	+ 40 + 4	+ 57 0	+ 73 + 37	+ 57 0	+ 98 + 62	+ 57 0	+ 226 + 190	315	355
						+ 57 0	+ 244 + 208	355	400
+ 63 0	+ 45 + 5	+ 63 0	+ 80 + 40	+ 63 0	+ 108 + 68	+ 63 0	+ 272 + 242	400	450
						+ 63 0	+ 292 + 252	450	500
Push fit		Drive fit		Press fit		Force fit			

2.6.3.4 ISO limits and fits, determining working limits.

Consider an example of a shaft and a housing used in a linkage:

Type of fit: 'Normal' clearance fit.

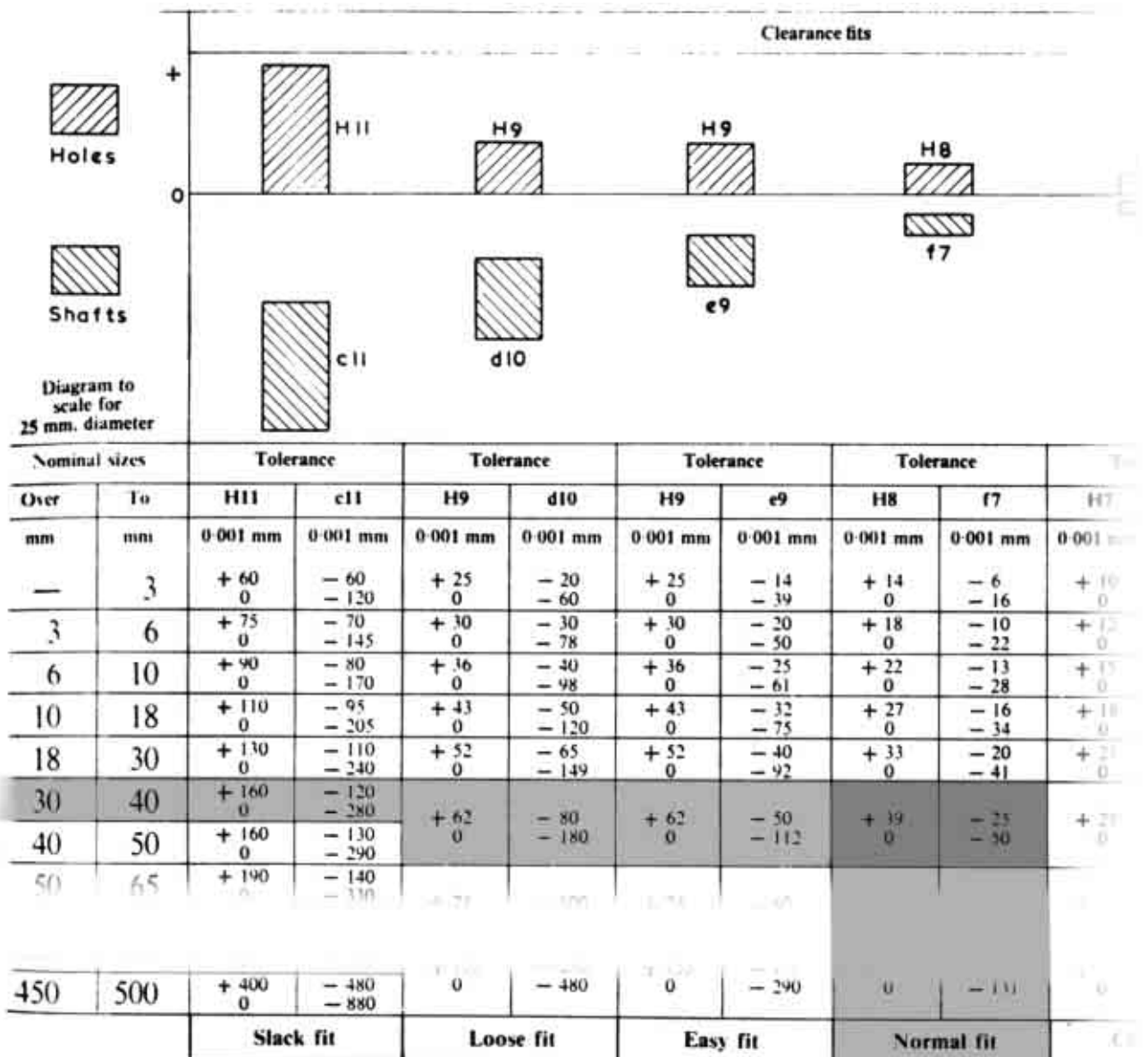
Basic or Nominal size: $\varnothing 40\text{mm}$

We will determine the actual working limits, the range of allowable sizes, for the shaft and the hole in the housing.

Look along the bottom of the ISO Fits Data Sheet 4500A and locate 'Normal Fit'. We will use this pair of columns to extract our tolerances.

The tolerances indicated are: 1st column **H8** for the hole (upper case **H**)
2nd column **f7** for the shaft (lower case **f**)

The actual tolerances depend upon the basic, or nominal, diameter as well as the class of fit. So, locate 40mm in the left hand **Nominal Sizes** column. Either the **30 - 40** or **40 - 50** range is acceptable in this case. Read across and note the tolerance values for the hole and the shaft, as shown below.



For the hole diameter we have a tolerance of: **+0.039mm -0.000mm**

For the shaft diameter we have a tolerance of: **-0.025mm -0.050mm**

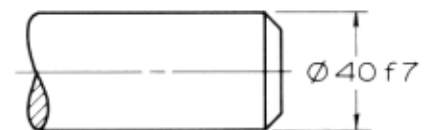
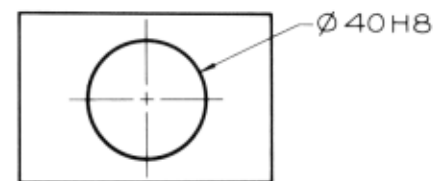
These tolerance values are simply added to the nominal size to obtain the actual allowable sizes.

Note that this is a clearance fit. As long as the hole and shaft are manufactured within the specified tolerances the hole will **always** be either slightly oversize or spot on the nominal size and the shaft will **always** be slightly undersize. This ensures that there will **always** be a free clearance fit.

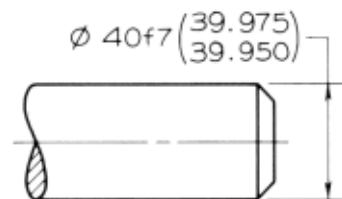
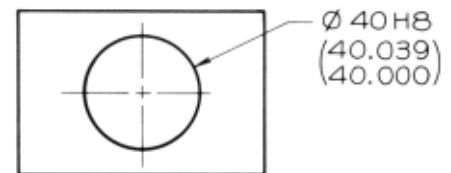
These tolerances may be expressed on a drawing in several ways:

1) Simply as the nominal size with the tolerance class.

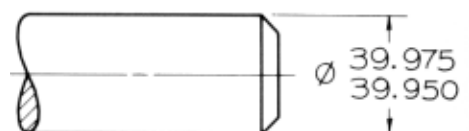
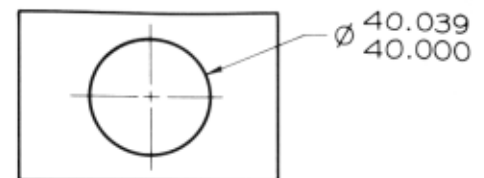
This is not always preferred as the machine operator has to calculate the working limits.



2) The nominal size with the tolerance class as above with the calculated working limits included.



3) The calculated working limits only.



ISO Symbol		Description	More clearance ←
Hole Basis	Shaft Basis		
H11/c11	C11/h11	Loose running fit for wide commercial tolerances or allowances on external members	← Clearance fits →
H9/d9	D9/h9	Free running fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures	
H8/f7	F8/h7	Close running fit for running on accurate machines and for accurate location at moderate speeds and journal pressures	
H7/g6	G7/h6	Sliding fit not intended to run freely but to move and turn freely and locate accurately	
H7/h6	H7/h6	Locational clearance fit provides snug fit for locating stationary parts but can be freely assembled and disassembled	← Transition fits →
H7/k6	K7/h6	Locational transition fit for accurate location; a compromise between clearance and interference	
H7/n6	N7/h6	Locational transition fit for more accurate location where greater interference is permissible	
H7/p6*	P7/h6	Locational interference fit for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements	← Interference fits →
H7/s6	S7/h6	Medium drive fit for ordinary steel parts or shrink fits on light sections; the tightest fit usable with cast iron.	
H7/u6	U7/h6	Force fit suitable for parts that can be highly stressed or for shrink fits where the heavy pressing forces required are impractical	