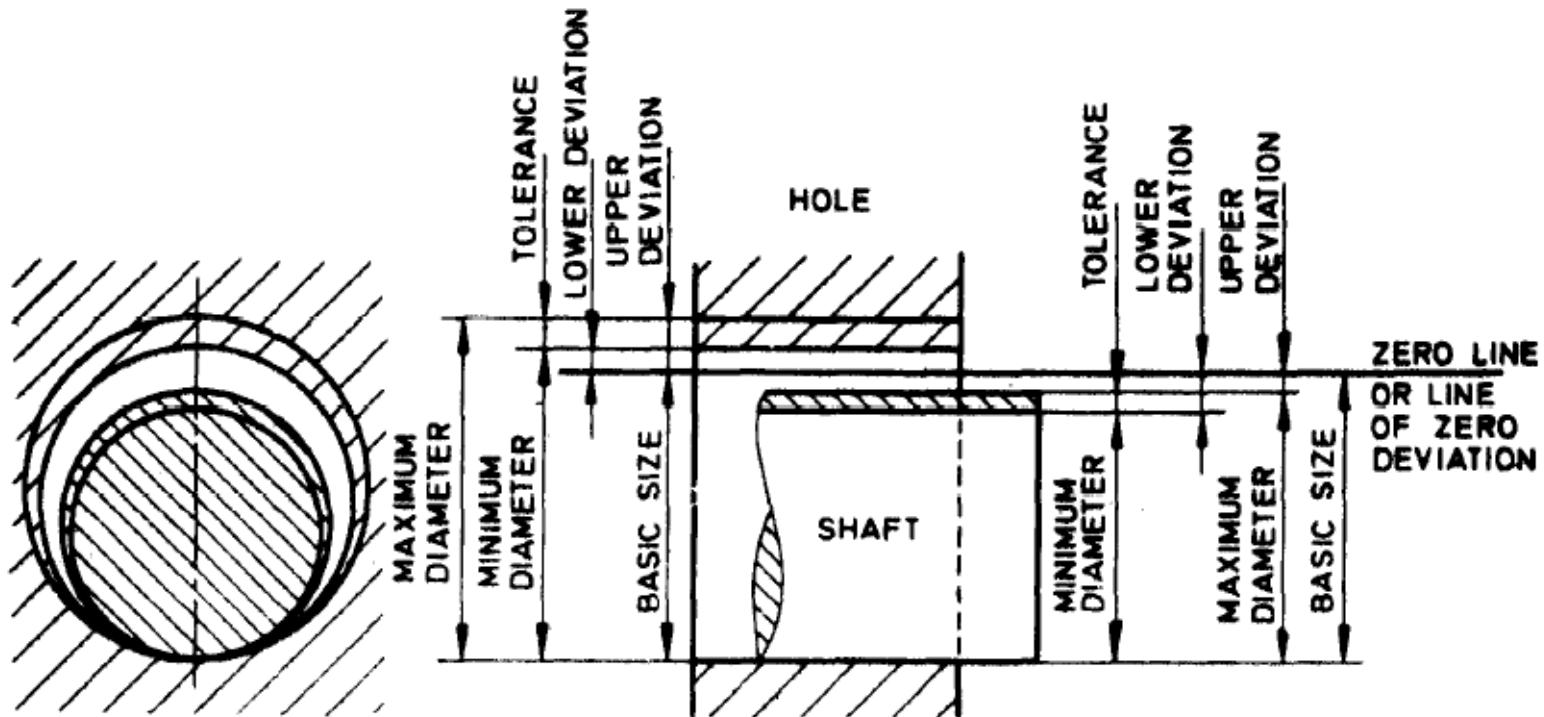


SYSTEM OF FITS AND TOLERANCES

- The standard reference temperature is 20 C for industrial measurements and, consequently, for dimensions defined by the system.
- Due to the inevitable inaccuracy of manufacturing methods, a part cannot be made precisely to a given dimension, the difference between maximum and minimum limits of size is the tolerance.
- When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a fit.



Tolerance

- How to decide tolerance?
 - Functional requirements of mating parts
 - Cost of production
 - Available manufacturing process
- Choose as coarse tolerance as possible without compromising functional requirements
- Proper balance between cost and quality of parts

HOLE

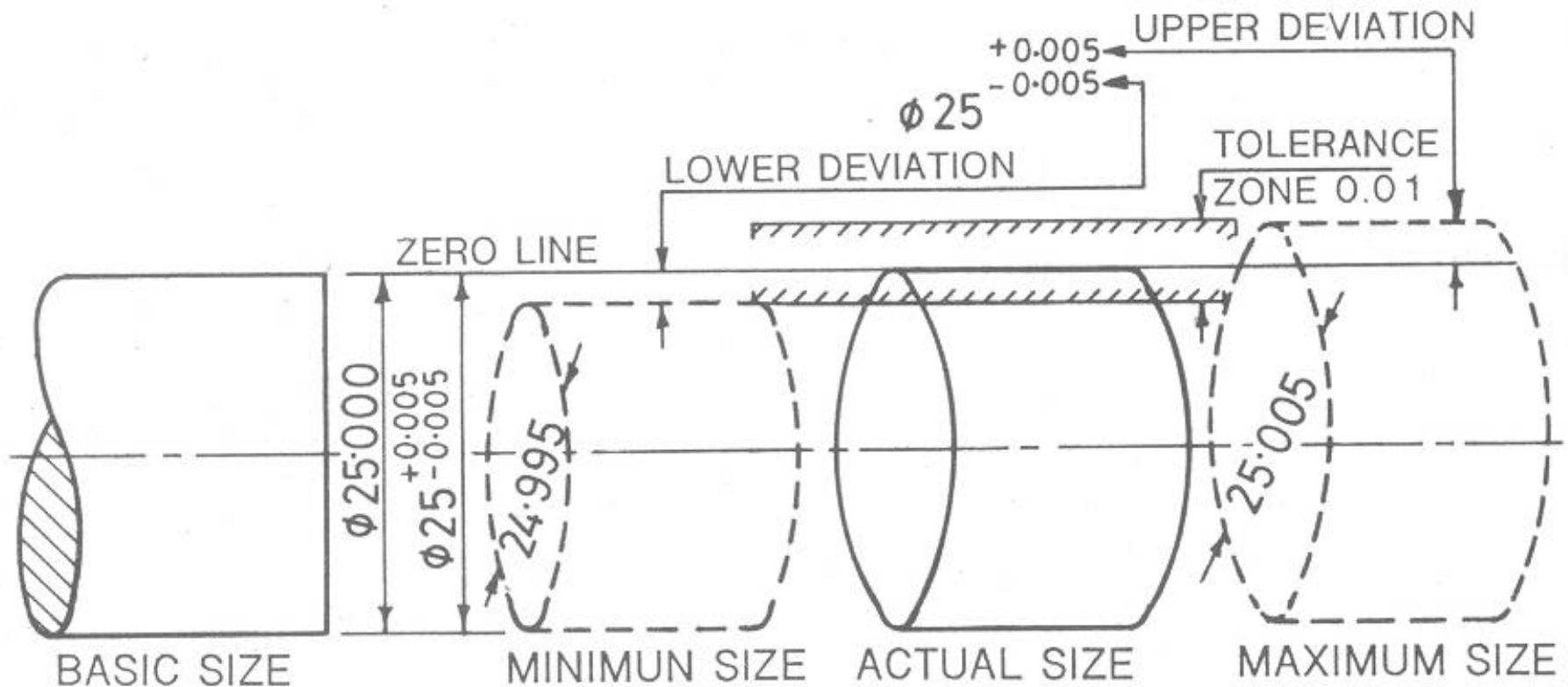
SHAFT

Max Hole size – Basic Size = Upper Deviation

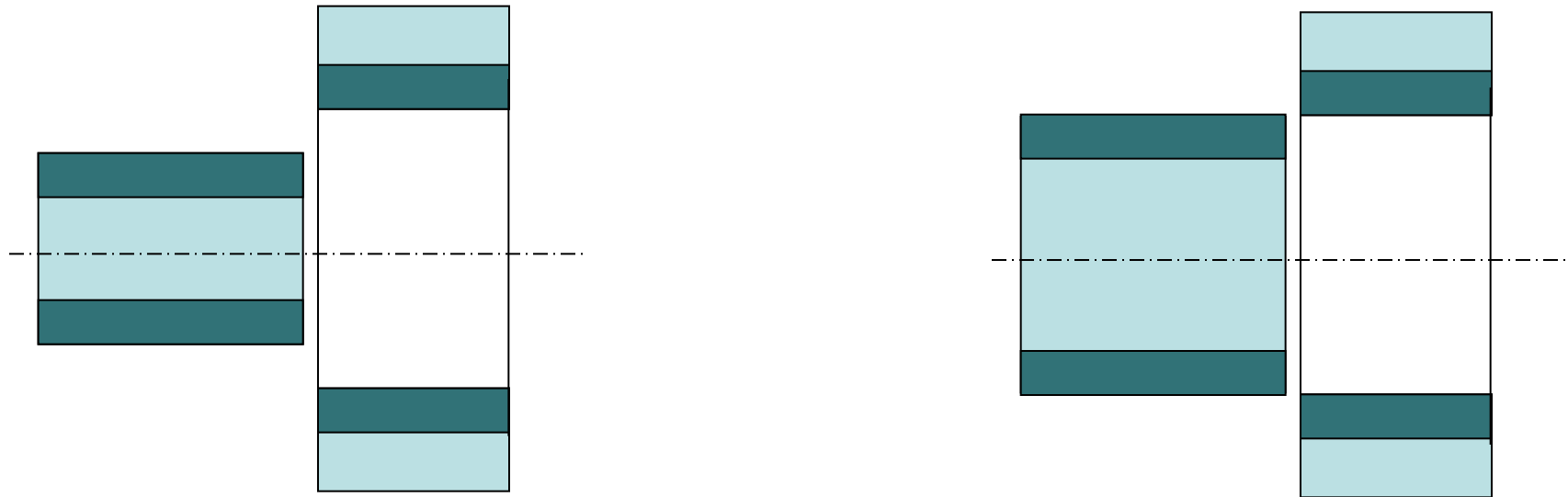
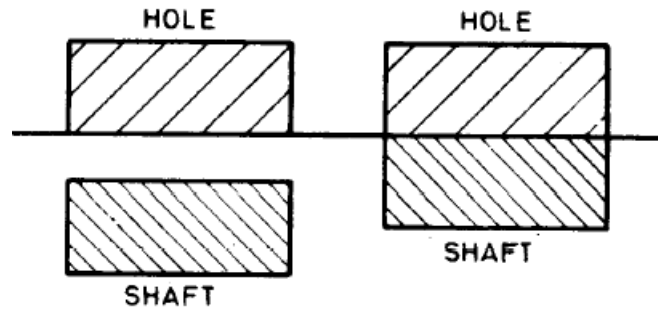
Max shaft size – Basic Size = Upper Deviation

Min Hole size – Basic Size = Lower Deviation

Min shaft size – Basic Size = Lower Deviation



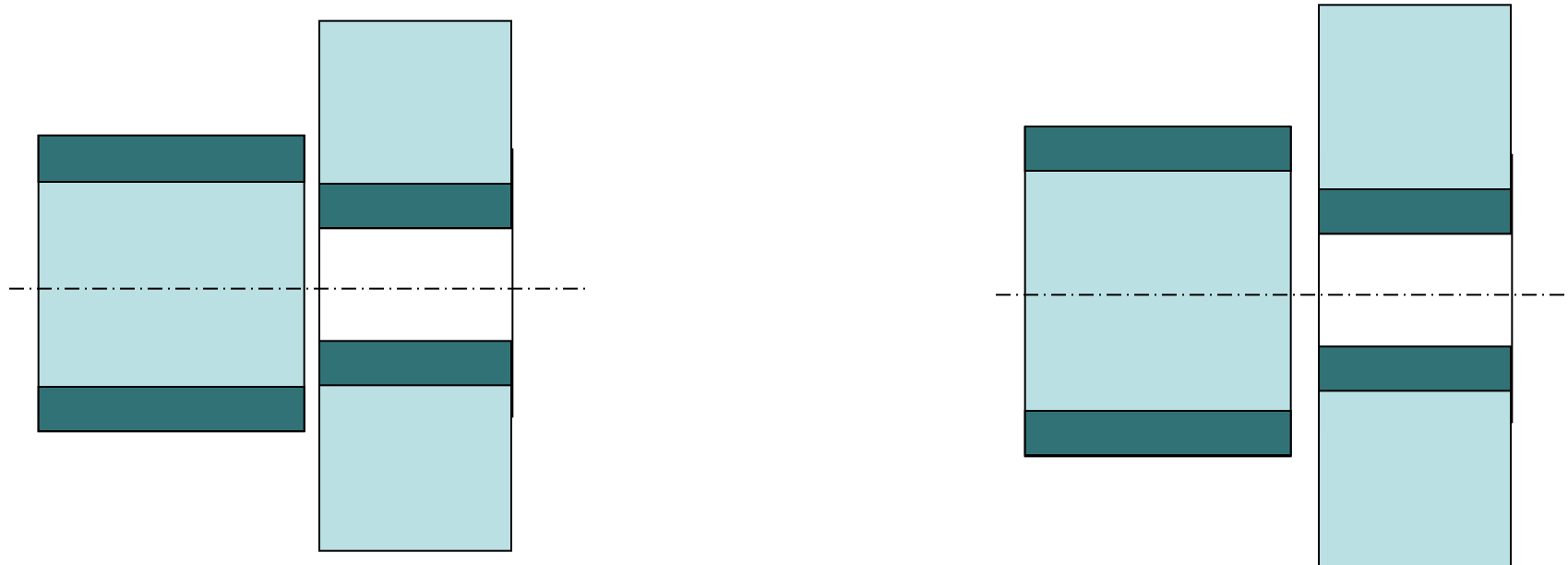
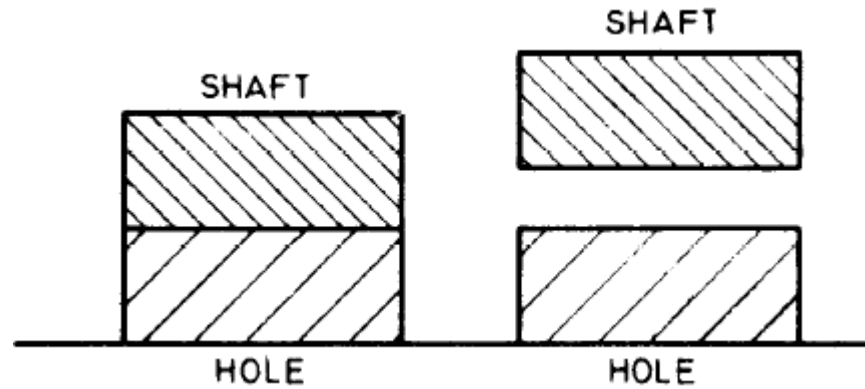
CLEARANCE FIT



Maximum shaft dimension < Minimum hole dimension

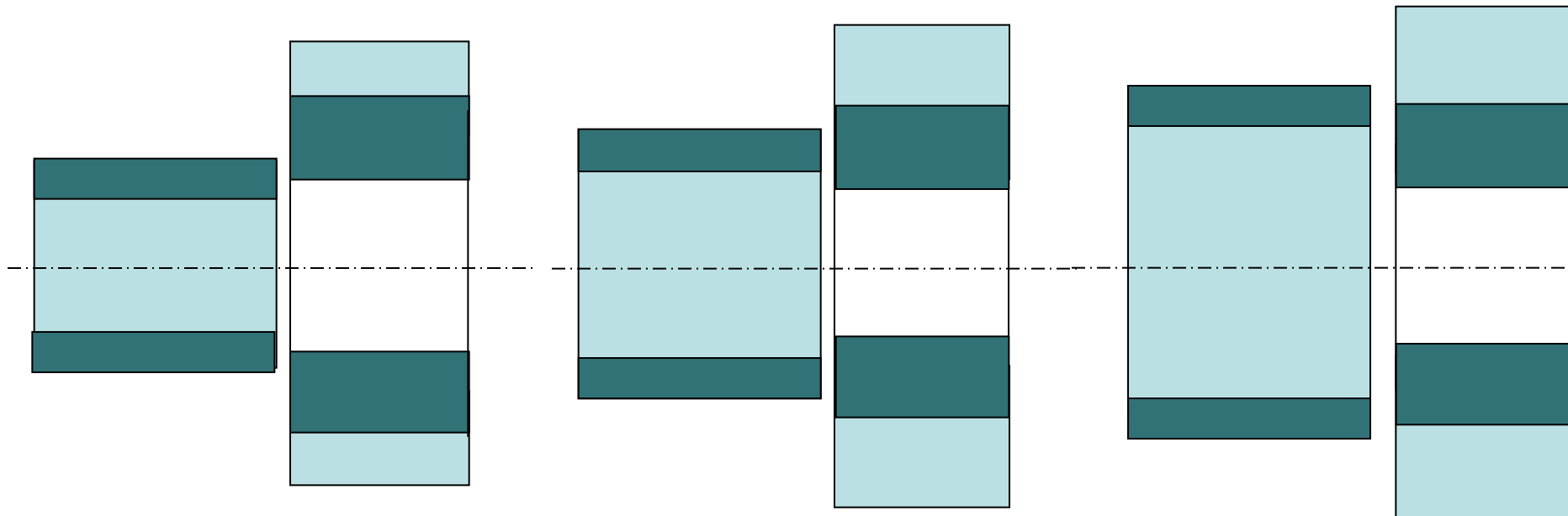
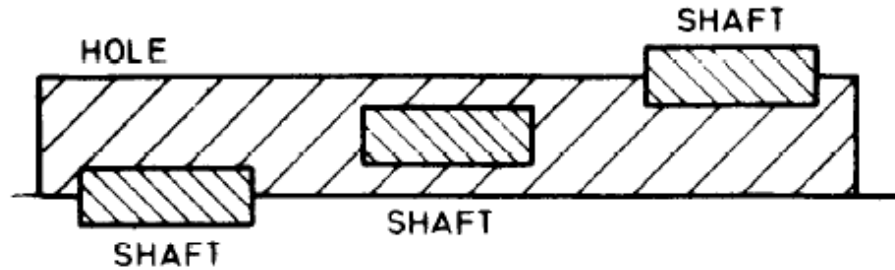
FIT - condition of looseness or tightness between two mating parts being assembled together

INTERFERENCE FIT



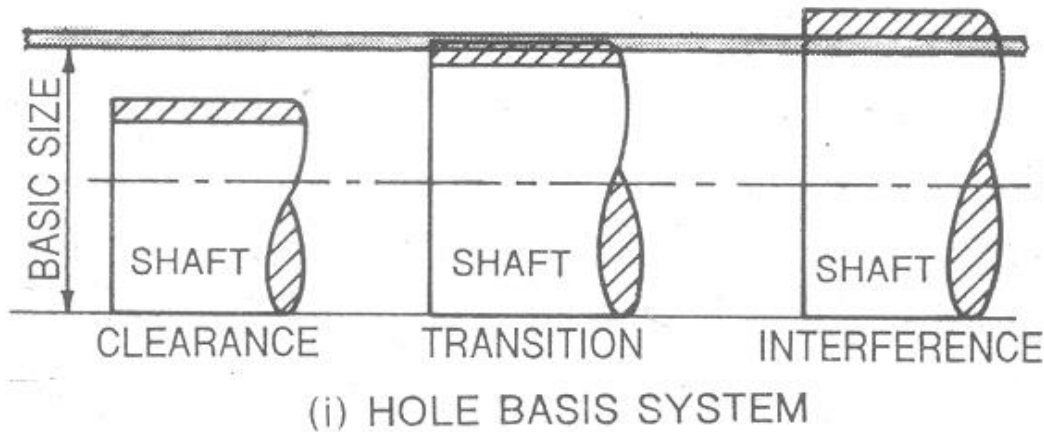
Maximum Hole size < Minimum Shaft size

TRANSITION FIT



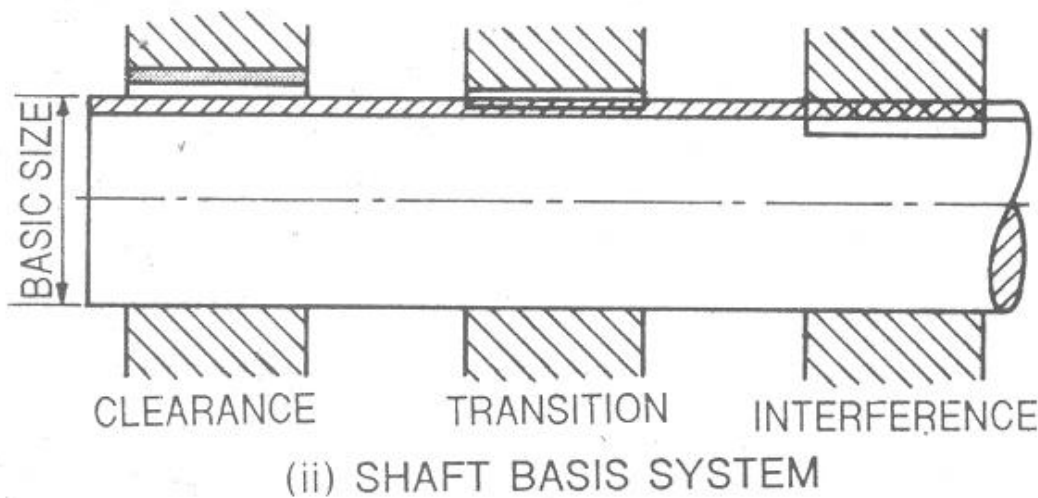
Obtained by overlapping of tolerance zones of shaft and hole
.....Does not guarantee neither clearance nor interference fit

To obtain different types of fits, it is general practice to vary tolerance zone of one of the mating parts



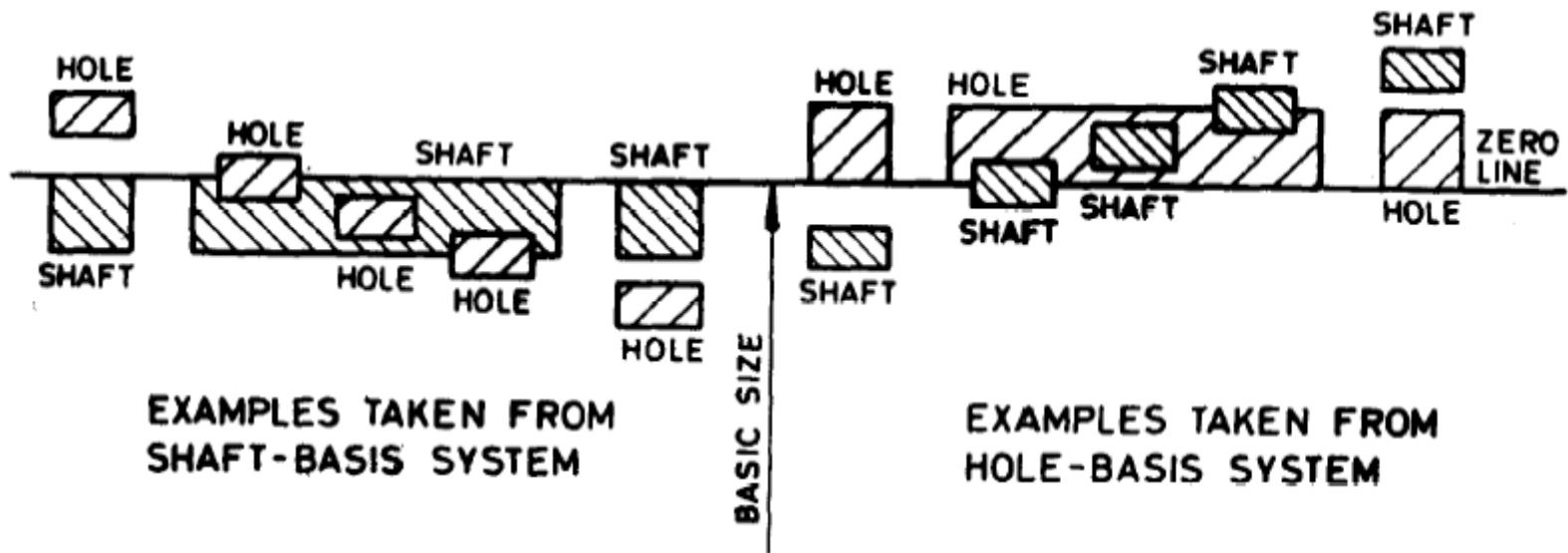
HOLE BASED SYSTEM-

Size of hole is kept constant, shaft size is varied to get different fits.



SHAFT BASED SYSTEM-

Size of shaft is kept constant, hole size is varied to get different fits.



A fit is indicated by the basic size common to both components, followed by symbol corresponding to each component, the hole being quoted first.

E.g. 45 H8/g7

Representation of Tolerance

1) Letter Symbol

Basic Size → 45 $\begin{matrix} \swarrow \\ \text{E8} \\ \searrow \\ \text{e7} \end{matrix}$

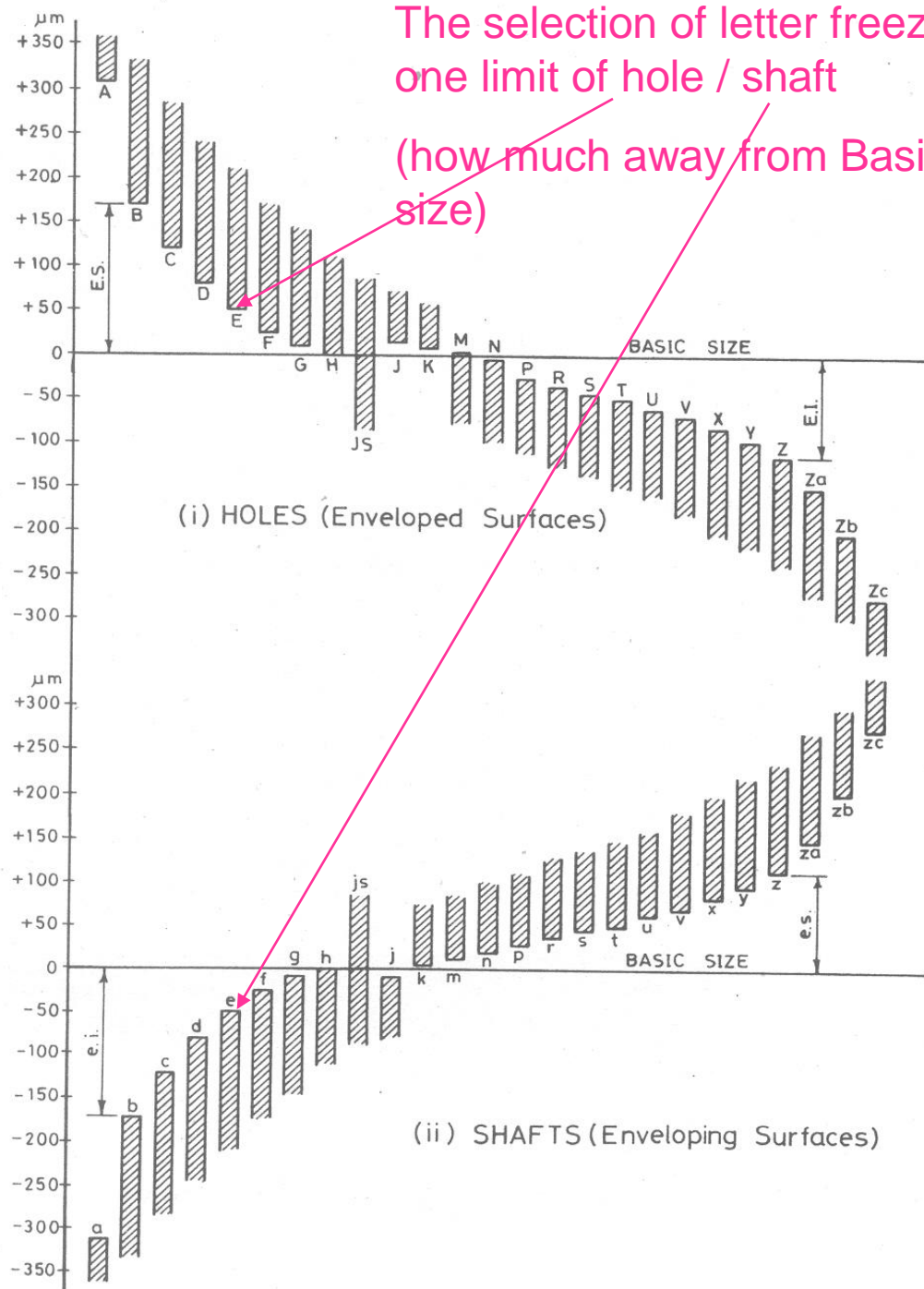
One can have different possible combinations; eg. 45H6g7, 45H8r6, 45E5p7

E.S. – upper deviation

E.I. – lower deviation

H : lower deviation of hole is zero

h : upper deviation of shaft is zero



Representation of Tolerance

2) Number or Grade

IT01, IT0, IT1,....IT16

Tolerance Grade defines range of dimensions (dimensional variation)

There are manufacturing constraints on tolerance grade chosen

Tolerance grade	Manufacturing process and applications	Machine required
IT01, IT0 IT1 to IT5	Super finishing process, such as lapping, diamond boring etc. Use: Gauges	Super finishing machines
IT6	Grinding	Grinding machines
IT7	Precision turning, broaching, honing	Boring machine, honing machine
IT8	Turning, boring and reaming	Lathes, capstan and automats
IT9	Boring	Boring machines
IT10	Milling, slotting, planing, rolling and extrusion	Milling machine, slotting machine, planing machine and extruders
IT11	Drilling, rough turning	Drilling machine, lathes
IT12, IT13, IT14	Metal forming processes	Presses
IT15	Die casting, stamping	Die casting machine, hammer machine
IT16	Sand casting	—

FUNDAMENTAL TOLERANCES OF GRADES 01, 0 AND 1 TO 16

Diameter steps in mm	Values of tolerance in microns (1 micron = 0.001 mm)																	
	Tolerance grades																	
	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14*	15*	16*
To and inc 3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600
Over 3																		
To and inc 6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
Over 6																		
To and inc 10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
Over 10																		
To and inc 18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
Over 18																		
To and inc 30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
Over 30																		
To and inc 50	0.6	1	1.5	2.5	4	7	11	16	25	39	60	110	160	250	390	620	1000	1600
Over 50																		
To and inc 80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
Over 80																		
To and inc 120	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
Over 120																		
To and inc 180	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
Over 180																		
To and inc 250	2	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
Over 250																		
To and inc 315	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
Over 315																		
To and inc 400	3	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600
Over 400																		
To and inc 500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000

* Upto 1 mm, Grades 14 to 16 are not provided.

RANGE IN A GIVEN TOLERANCE GRADE

TABLE 18-14(i)
(Values in microns)

Tolerances of holes						Tolerances of shafts				
Nominal sizes	H7	H8	H9	H10	H11	d9	e8	f7	g6	h6
From 1 Upto 3	+10 0	+14 0	+ 25 0	+ 40 0	+ 60 0	- 20 - 45	- 14 - 28	- 6 - 16	- 2 - 8	0 - 6
Over 3 Upto 6	+12 0	+18 0	+ 30 0	+ 45 0	+ 75 0	- 30 - 60	- 20 - 38	- 10 - 22	- 4 -12	0 - 8
Over 6 Upto 10	+15 0	+22 0	+ 36 0	+ 58 0	+ 90 0	- 40 - 75	- 25 - 47	- 13 - 28	- 5 -14	0 - 9
Over 10 Upto 18	+18 0	+27 0	+ 43 0	+ 70 0	+110 0	- 50 - 93	- 32 - 59	- 16 - 34	- 6 -17	0 -11
Over 18 Upto 30	+21 0	+33 0	+ 52 0	+ 84 0	+130 0	- 65 -117	- 40 - 73	- 20 - 41	- 7 -20	0 -13
Over 30 Upto 50	+25 0	+39 0	+ 62 0	+100 0	+160 0	-80 -142	- 50 - 89	- 25 - 50	- 9 -25	0 -16
Over 50 Upto 80	+30 0	+46 0	+ 76 0	+120 0	+190 0	-100 -174	- 60 -105	- 30 - 60	-10 -29	0 -19
Over 80 Upto 120	+35 0	+54 0	+ 87 0	+140 0	+220 0	-120 -207	- 72 -126	- 36 - 71	-12 -34	0 -22
Over 120 Upto 180	+40 0	+63 0	+100 0	+160 0	+250 0	-145 -245	-85 -148	- 43 - 83	-14 -39	0 -25
Over 180 Upto 250	+45 0	+72 0	+115 0	+185 0	+290 0	-170 -285	-100 -172	- 50 - 96	-15 -44	0 -29
Over 250 Upto 315	+52 0	+81 0	+130 0	+210 0	+320 0	-190 -320	-110 -191	- 56 -108	-17 -49	0 -32
Over 315 Upto 400	+57 0	+89 0	+140 0	+230 0	+360 0	-210 -350	-125 -214	- 62 -119	-18 -54	0 -35
Over 400 Upto 500	+63 0	+97 0	+155 0	+250 0	+400 0	-230 -385	-135 -232	- 68 -131	-20 -60	0 -40

Note: Upto means including. Over means excluding.

TABLE 18-14(ii)
(Values in microns)

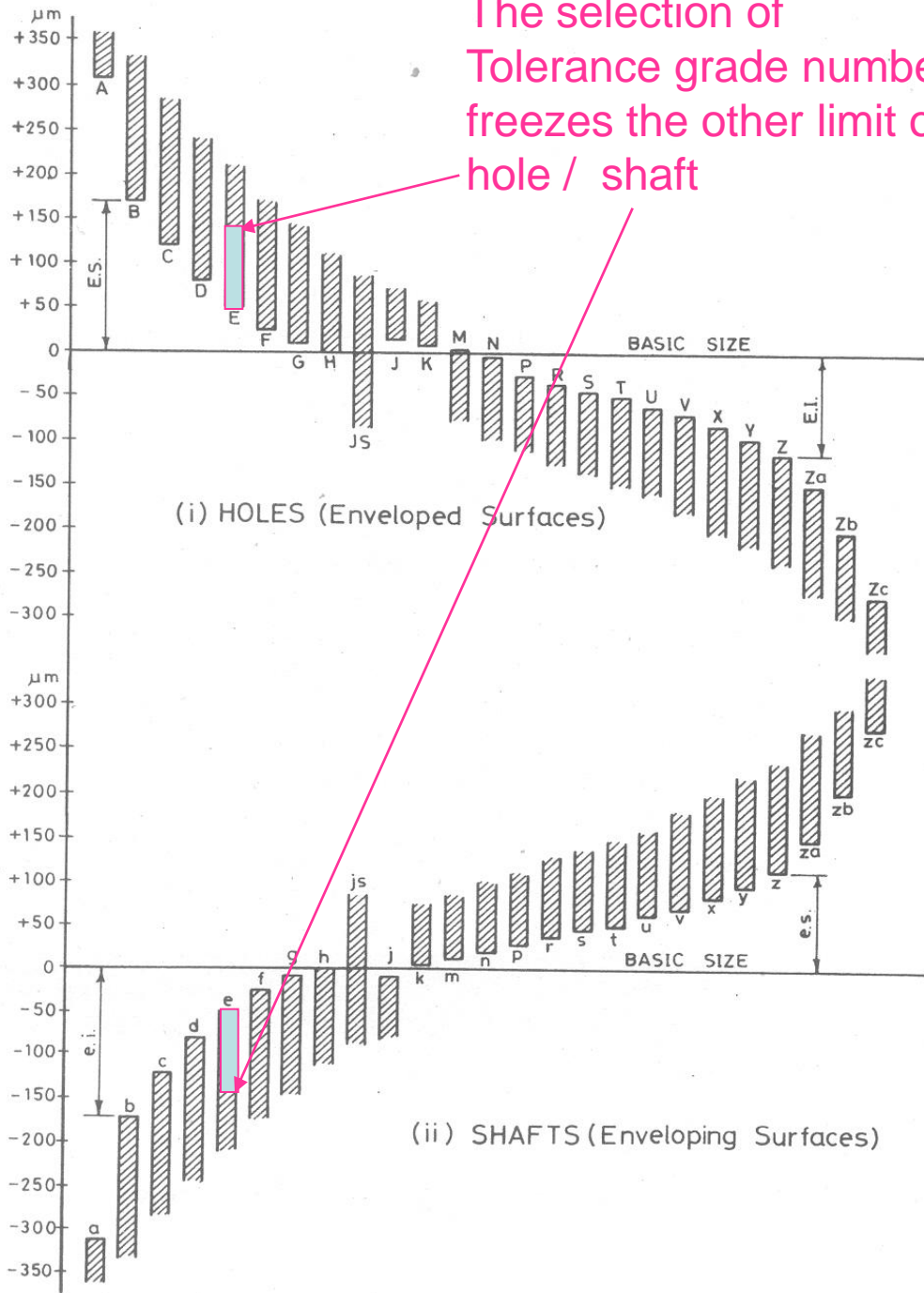
Nominal sizes	Tolerances of holes						Tolerances of shafts			
	D10	E9	F8	G7	JS7	K7	j6	k6	n6	p6
From 1 Upto 3	+ 60 + 20	+ 39 + 14	+ 20 + 6	+12 + 2	+ 5 - 5	0 -10	+ 3 - 3	+ 6 0	+10 + 4	+ 12 + 6
Over 3 Upto 6	+ 78 + 30	+ 50 + 20	+ 28 + 10	+16 + 4	+ 6 - 6	+ 3 - 9	+ 4 - 4	+ 9 + 1	+16 + 8	+ 20 + 12
Over 6 Upto 10	+ 98 + 40	+ 61 + 25	+ 35 + 13	+20 + 5	+ 7.5 - 7.5	+ 5 -10	+ 4.5 - 4.5	+10 + 1	+19 +10	+ 24 + 15
Over 10 Upto 18	+120 + 50	+ 75 + 32	+ 43 + 16	+24 + 6	+ 9 - 9	+ 6 -12	+ 5.5 - 5.5	+12 + 1	+23 +12	+ 29 + 18
Over 18 Upto 30	+149 + 65	+ 92 + 40	+ 53 + 20	+28 + 7	+10.5 -10.5	+6 -15	+ 6.5 - 6.5	+15 + 2	+28 +15	+ 35 + 22
Over 30 Upto 50	+180 + 80	+112 + 50	+ 64 + 25	+34 + 9	+12.5 -12.5	+ 7 -18	+ 8 - 8	+18 + 2	+33 +17	+ 42 + 26
Over 50 Upto 80	+220 +100	+134 + 60	+ 76 + 30	+40 +10	+15 -15	+ 9 -21	+ 9.5 - 9.5	+21 + 2	+39 +20	+ 51 + 32
Over 80 Upto 120	+260 +120	+159 + 72	+ 90 + 36	+47 +12	+17.5 -17.5	+10 -25	+11 -11	+25 + 3	+45 +23	+ 59 + 37
Over 120 Upto 180	+305 +145	+185 + 85	+106 + 43	+54 +14	+20 -20	+12 -28	+12.5 -12.5	+28 + 3	+52 +27	+ 68 + 43
Over 180 Upto 250	+355 +170	+215 +100	+122 + 50	+61 +15	+23 -23	+13 +33	+14.5 -14.5	+33 + 4	+60 +31	+ 79 + 50
Over 250 Upto 315	+400 +190	+240 +110	+135 + 55	+69 +17	+26 -26	+16 -36	+16 -16	+36 + 4	+66 +34	+ 88 + 56
Over 315 Upto 400	+440 +210	+265 +125	+151 + 69	+75 +18	+28.5 -28.5	+17 -40	+18 -18	+40 + 4	+73 +37	+ 98 + 62
Over 400 Upto 500	+480 +230	+290 +135	+165 + 68	+83 +20	+31.5 -31.5	+18 -45	+20 -20	+45 + 5	+80 +40	+108 + 68

TABLE 18-14(iii)
(Values in microns)

Tolerances of holes					Tolerances of shafts					
Nominal sizes	C11	N7	P7	R7	S7	r6	s6	t6	u6	u6
From 1	+120	- 4	- 6	- 10	- 1	+ 16	+ 20	-	+ 24	+ 28
Upto 3	+ 60	-14	-16	- 20	- 24	+ 10	+ 14	-	+ 10	+ 18
Over 3	+145	- 4	- 8	- 11	- 15	+ 23	+ 27	-	+ 31	+ 35
Upto 6	+ 70	-16	-20	- 23	- 27	+ 15	+ 19	-	+ 23	+ 23
Over 6	+170	- 4	- 9	- 13	- 17	+ 28	+ 32	-	+ 37	+ 43
Upto 10	+ 80	-19	-24	- 28	- 32	+ 19	+ 28	-	+ 28	+ 28
Over 10	+205	- 5	-11	- 16	- 21	+ 34	+ 39	-	+ 44	+ 51
Upto 18	+ 95	-23	-29	- 34	- 39	+ 23	+ 28	-	+ 33	+ 33
Over 18	+240	- 7	-14	- 20	- 27	+ 41	+ 48	+ 54	+ 61	+ 62
Upto 30	+110	-28	-35	- 41	- 48	+ 28	+ 35	+ 41	+ 41	+ 41
Over 30	+280	- 8	-17	- 25	- 34	+ 50	+ 59	+ 64	+ 76	+ 85
Upto 40	+120	-	-	-	-	-	-	+ 48	+ 60	+ 60
Over 40	+290	-33	-42	- 50	- 59	+ 34	+ 43	+ 70	+ 86	+ 95
Upto 50	+130	-	-	-	-	-	-	+ 54	+ 70	+ 70
Over 50	+330	- 9	-21	- 30	- 42	+ 60	+ 72	+ 85	+106	+117
Upto 65	+140	-	-	- 60	- 72	+ 41	+ 53	+ 66	+ 87	+ 87
Over 65	+340	-39	-51	- 32	- 48	+ 62	+ 78	+ 94	+121	+132
Upto 80	+150	-	-	- 62	- 78	+ 43	+ 59	+ 75	+102	+102
Over 80	+390	-10	-24	- 38	- 58	+ 73	+ 93	+113	+146	+159
Upto 100	+170	-	-	- 73	- 93	+ 51	+ 71	+ 91	+124	+124
Over 100	+400	-45	-59	- 41	- 66	+ 76	+101	+126	+166	+175
Upto 120	+180	-	-	- 76	-101	+ 54	+ 79	+104	+144	+144
Over 120	+450	-12	-28	- 48	- 77	+ 88	+117	+147	+195	+230
Upto 140	+200	-	-	- 88	-117	+ 63	+ 92	+122	+170	+170
Over 140	+480	-52	-68	- 50	- 85	+ 93	+133	+171	+235	+250
Upto 180	+210	-	-	- 93	-133	+ 65	+100	+134	+190	+190
Over 180	+570	-14	-33	- 60	-105	+113	+169	+225	+330	+330
Upto 250	+240	-60	-79	-113	-169	+ 77	+122	+166	+236	+236
Over 250	+650	-14	-36	- 74	-138	+130	+202	+272	+382	+402
Upto 315	+300	-66	-88	-130	-202	+ 94	+158	+218	+350	+315
Over 315	+760	-16	-41	- 87	-169	+150	+244	+330	+471	+492
Upto 400	+360	-73	-98	-150	-224	+108	+190	+268	+390	+390
Over 400	+880	-17	-45	-103	-209	+172	+292	+400	+580	+603
Upto 500	+440	-80	-108	-172	-292	+126	+232	+330	+490	+490

Representation of Tolerance

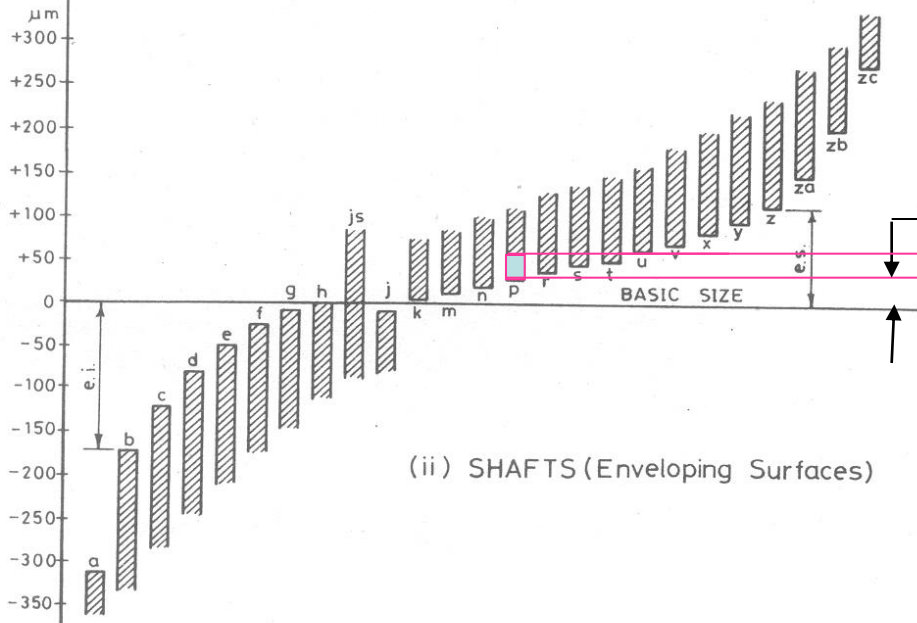
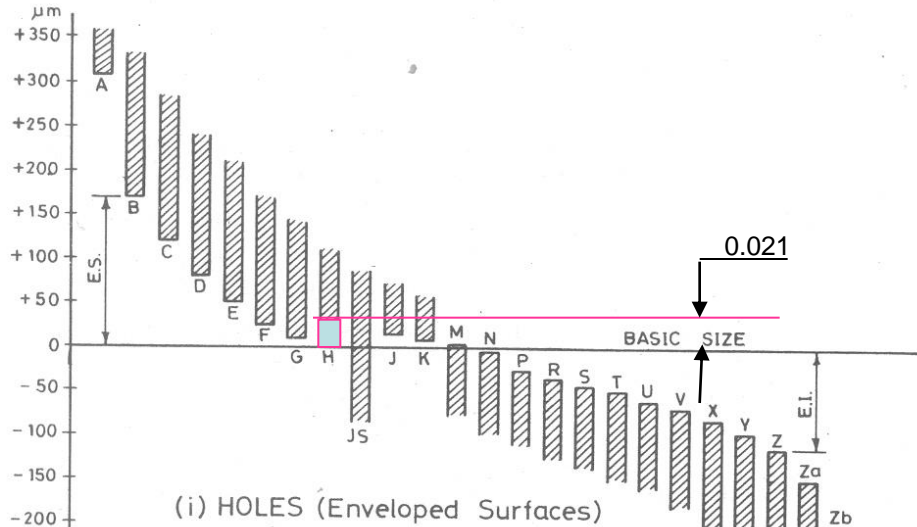
The selection of Tolerance grade number freezes the other limit of hole / shaft



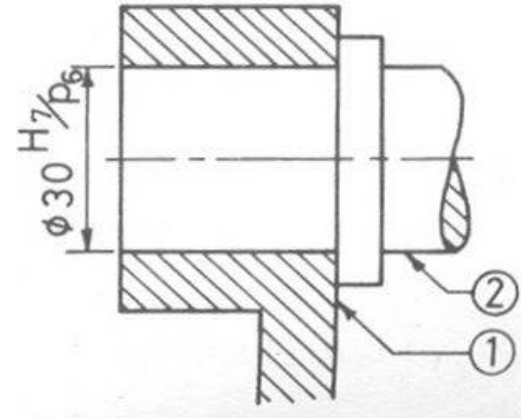
Nominal sizes	Tolerances of holes					Tolerances of shafts				
	H7	H8	H9	H10	H11	d9	e8	f7	g6	h6
From 1 Upto 3	+10 0	+14 0	+25 0	+40 0	+60 0	-20 -45	-14 -28	-6 -16	-2 -8	0 -6
Over 3 Upto 6	+12 0	+18 0	+30 0	+45 0	+75 0	-30 -60	-20 -38	-10 -22	-4 -12	0 -8
Over 6 Upto 10	+15 0	+22 0	+36 0	+58 0	+90 0	-40 -75	-25 -47	-13 -28	-5 -14	0 -9
Over 10 Upto 18	+18 0	+27 0	+43 0	+70 0	+110 0	-50 -93	-32 -59	-16 -34	-6 -17	0 -11
Over 18 Upto 30	+21 0	+33 0	+52 0	+84 0	+130 0	-65 -117	-40 -73	-20 -41	-7 -20	0 -13
Over 30 Upto 50	+25 0	+39 0	+62 0	+100 0	+160 0	-80 -142	-50 -89	-25 -50	-9 -25	0 -16
Over 50 Upto 80	+30 0	+46 0	+76 0	+120 0	+190 0	-100 -174	-60 -105	-30 -60	-10 -29	0 -19

H : lower deviation of hole is zero

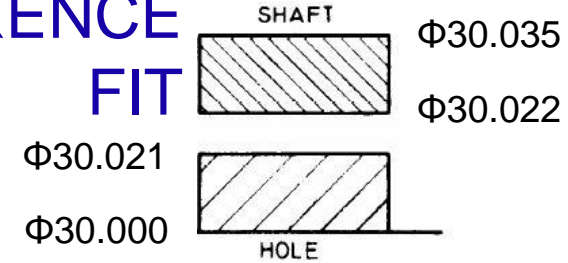
Representation of Fit



Together (Letter & Grade) on both mating components decide quality of fit



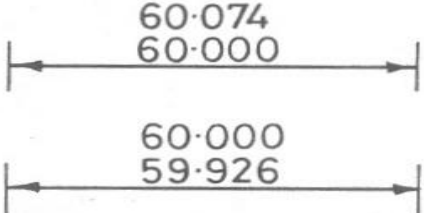
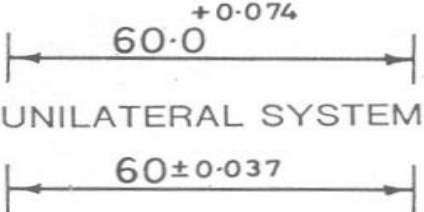
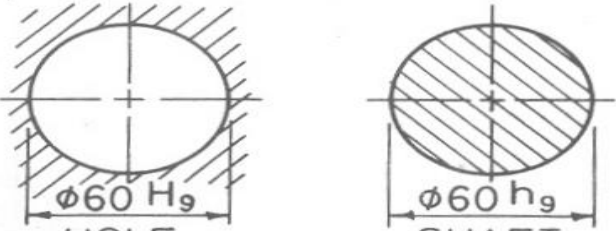
INTERFERENCE FIT



H7 : Tol Grade 7 mean 21μ variation (H means upper deviation zero)

p6 : Tol Grade 6 means 13μ variation (p means upper deviation is 22μ)

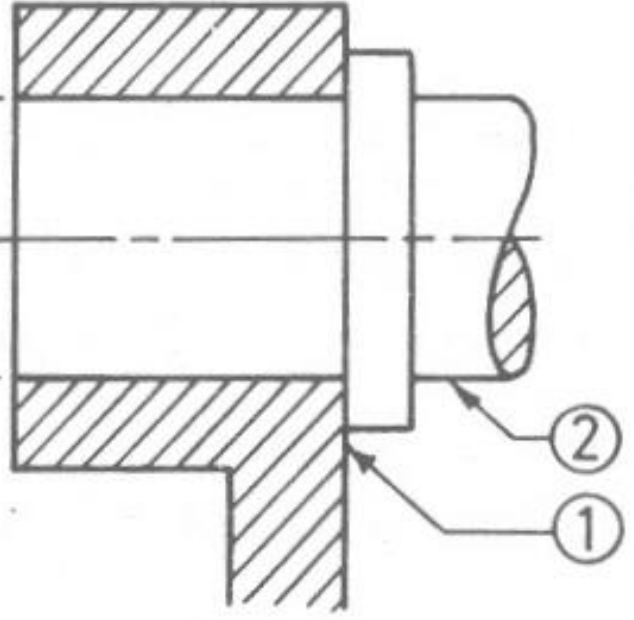
Tolerance on Components

METHOD	ILLUSTRATIONS
I	
II	 <p>UNILATERAL SYSTEM</p> <p>BILATERAL SYSTEM</p>
III	 <p>$\phi 60 H_9 = \phi 60 +0.000^{+0.074}$</p> <p>H – MEANS LOWER DEVIATION ZERO 9 – GRADE (IT9)</p> <p>$\phi 60 h_9 = \phi 60 -0.074^{-0.000}$</p>

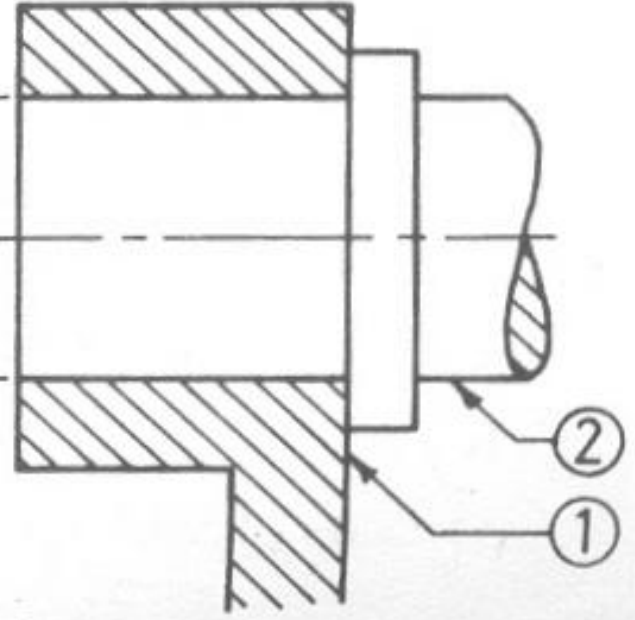
+0.025 } Part - 1
0.000 }

0.042 } Part - 2
0.026 }

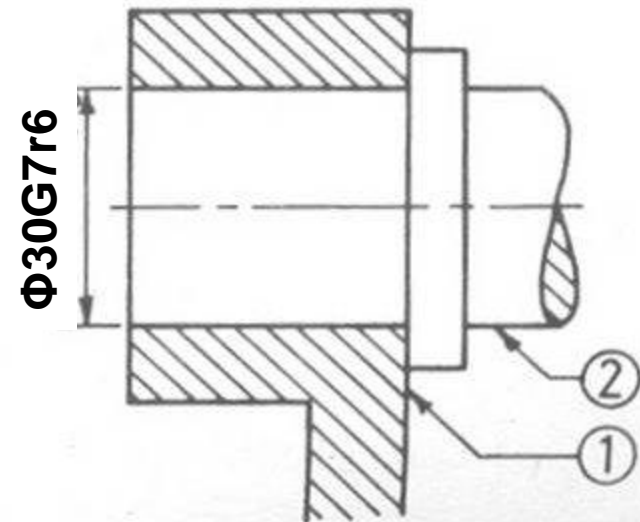
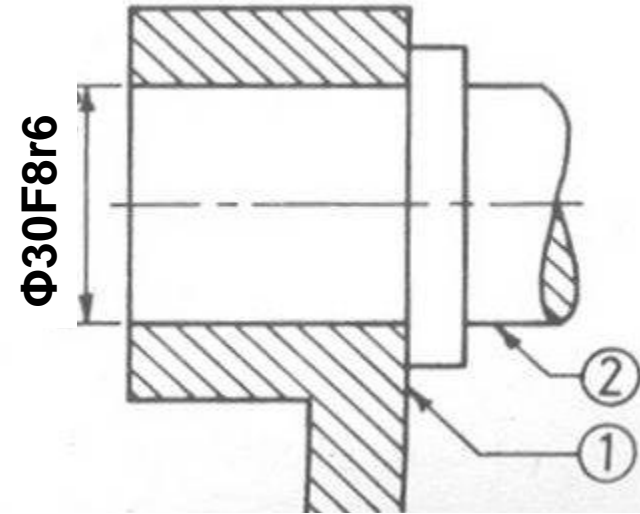
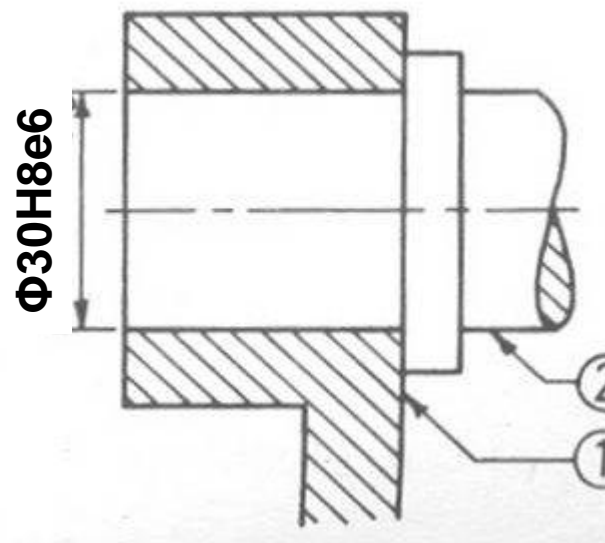
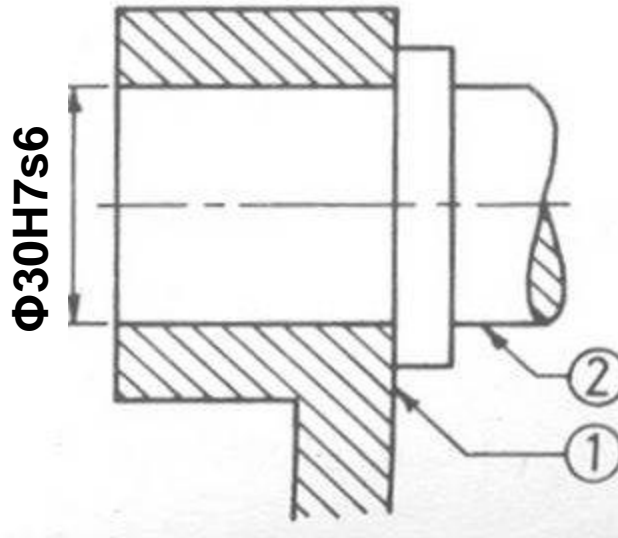
$\phi 30$



$\phi 30$ H7/p6



Estimate kind of fit



FITS APPLICATIONS

Interference fit

Shrink fit	H8/u8	Wheel steel tyres, bronze crowns on worm wheel hubs, couplings etc
Heavy drive fit	H7/s6	
Press fit	H7/r6	Coupling of shaft ends, bearing bushing in hubs, valve seats, gear wheels
Medium press fit	H7/p6	

Transition fit

Light press fit	H7/n6	gears and bearing bushes, shaft and wheel assembly fixed by feather key.
Force fit	H7/m6	parts of machine tools that must be dismantled without damage e.g. gears belt pulleys, couplings, fit bolts, inner ring of ball bearings
Push fit	H7/k6	belt pulleys, brake pulleys, gears and couplings as well as inner rings of ball bearings on shafts for average loading conditions
Easy push fit	H7/j6	parts which are frequently dismantled, but are secured by keys, e.g. pulleys, hand wheels, bushes, bearing shells, piston on piston rods, change gear trains

Clearance fit

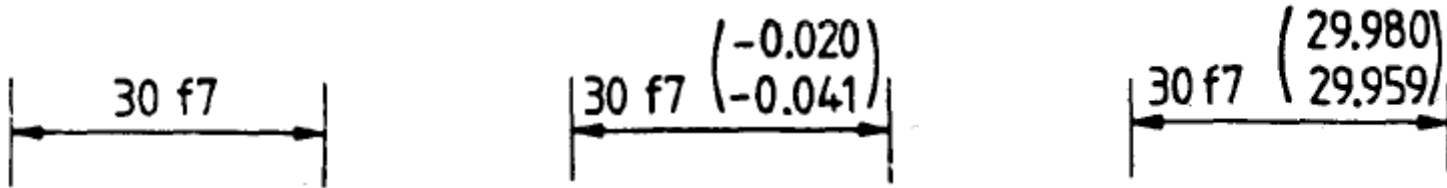
Precision sliding fit	H7/h6	sealing rings, bearing covers, milling cutters on milling mandrels
Close running fit	H7/g6	sleeve shafts, clutches, movable gears in change gear trains
Normal running fit	H7/f7	Sleeve bearings with high revolution, bearings on machine tool spindles
Easy running fit	H8/e8	Sleeve bearings with medium revolution, grease lubricated bearings of wheel boxes, gear sliding on shafts and sliding blocks
Loose running fit	H8/d9	Sleeve bearings with low revolution
Slack running fit	H8/c11	Oil seals with metal housings, multi-spline shafts
	H11/a11	Large clearance and widely used

FITS AND TOLERANCES

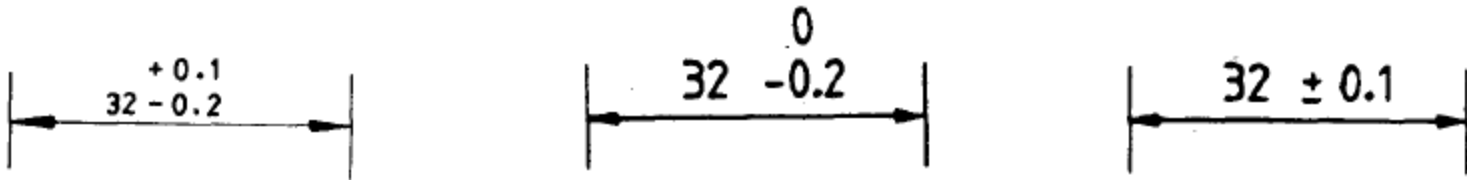
The components of the toleranced dimension shall be indicated in the following order:

- the basic size, and
- the tolerance symbol.

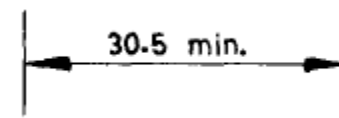
If, in addition to the symbols it is necessary to express the values of the deviations or the limits of size, the additional information shall be shown in brackets.



Permissible deviation

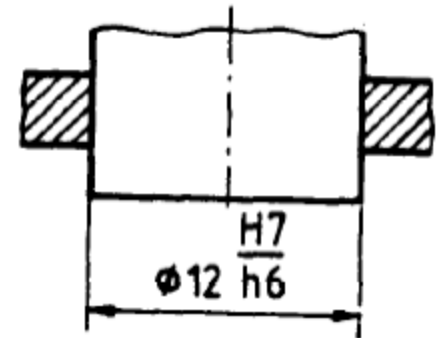
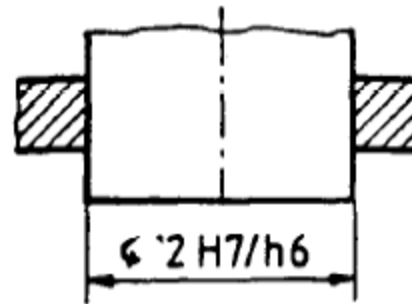
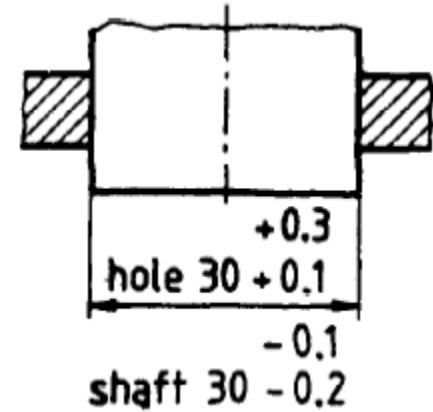


- If a dimension needs to be limited in one direction only, this should be indicated by adding "min" or "max" to the dimension.

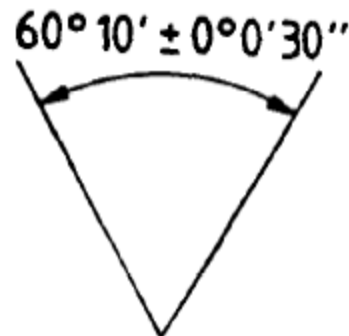
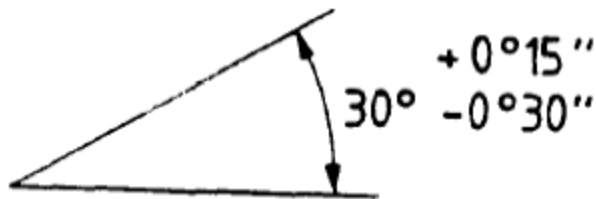


- The upper deviation or the upper limit of size shall be written in the upper position and the lower deviation or the lower limit of size in the lower position, irrespective of whether a hole or a shaft is tolerated.

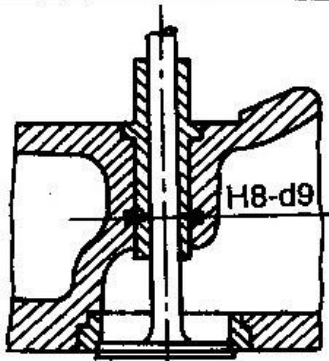
- The tolerance symbol for the hole shall be placed before that for the shaft or above it, the symbols being preceded by the basic size indicated once only.



Indication of Tolerances on Angular Dimensions

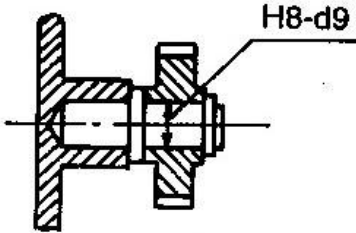


LOOSE RUNNING FIT



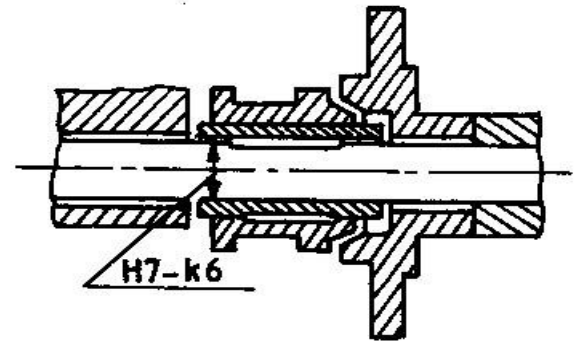
IC ENGINE EXHAUST VALVE IN GUIDE

LOOSE RUNNING FIT



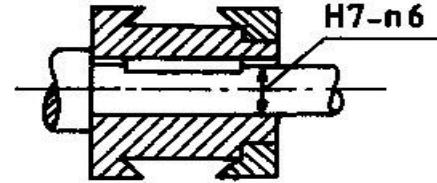
IDLER GEAR ON SPINDLE

PUSH FIT



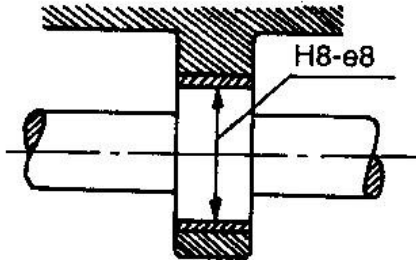
CLUTCH MEMBER KEyed TO SHAFT

LIGHT PRESS FIT



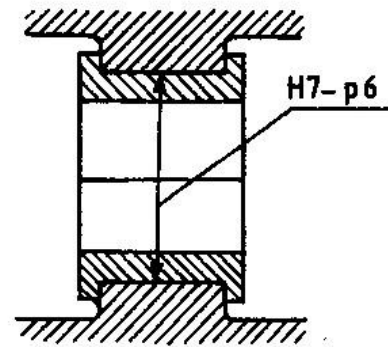
COMMUTATOR SHELL ON SHAFT

EASY RUNNING FIT



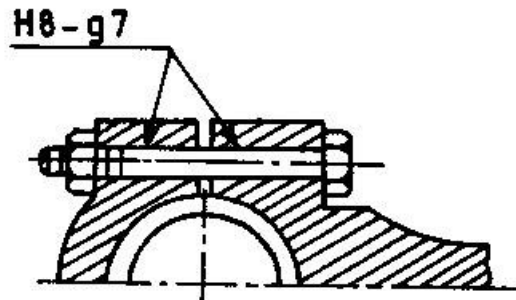
CAMSHAFT IN BEARING

MEDIUM PRESS FIT



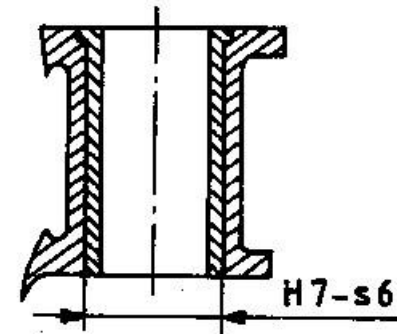
SPLIT JOURNAL BEARING

CLOSE RUNNING FIT



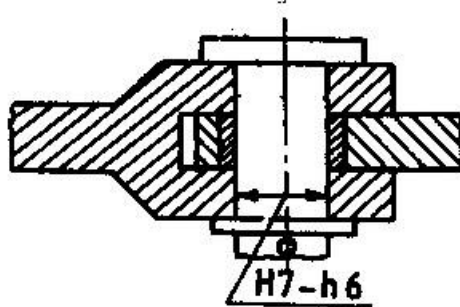
CONNECTING ROD BOLT

HEAVY DRIVE FIT



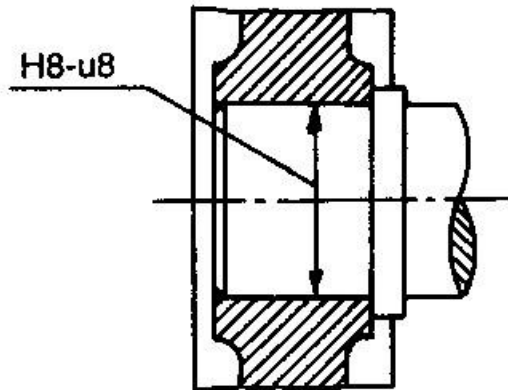
CYLINDER LINER IN BLOCK

LOCATION SLIDING FIT



VALVE MECHANISM LINK PIN

SHRINK FIT



LOCOMOTIVE WHEEL ON AXLE

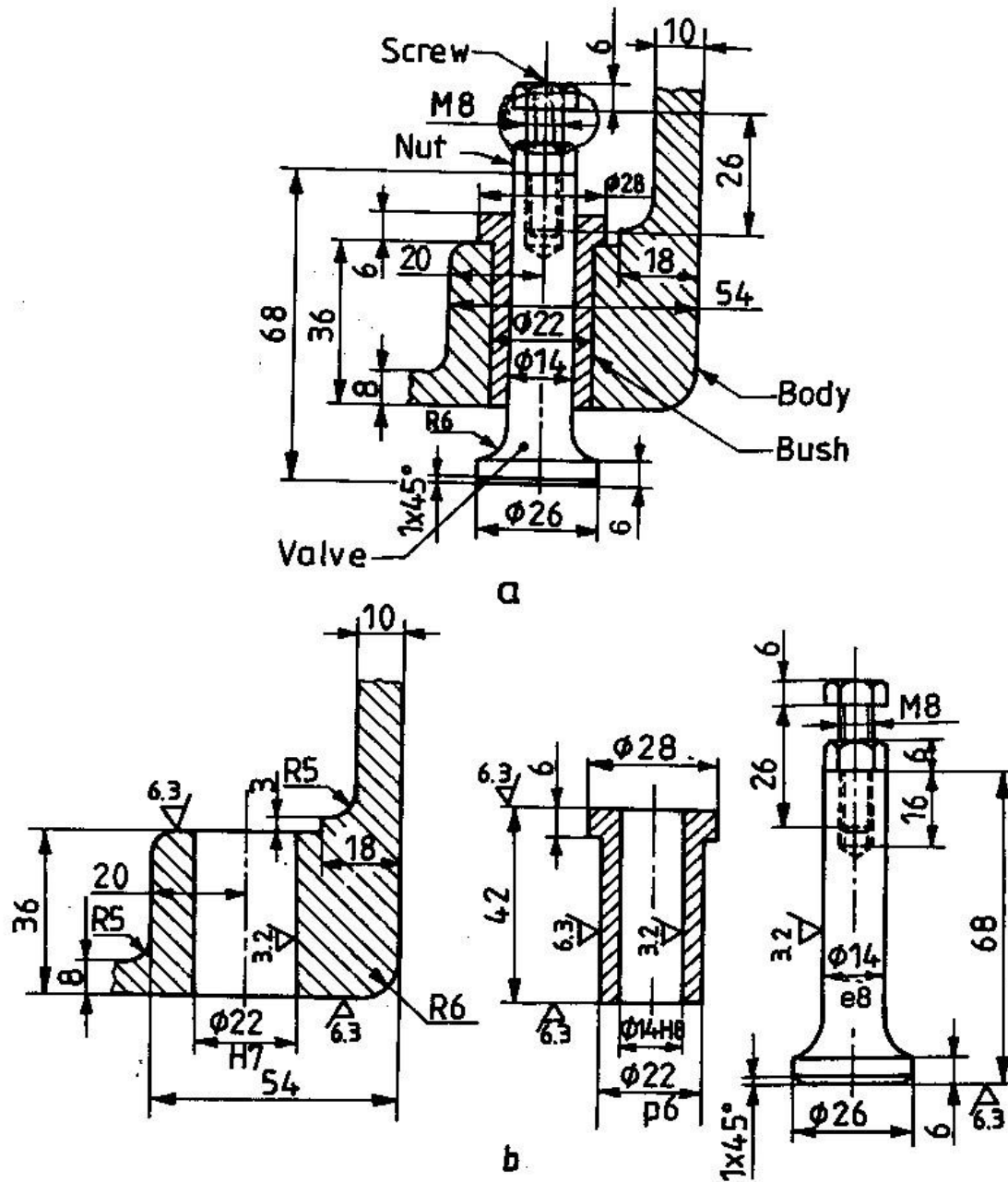


Fig. 8.1 Tappet in guide

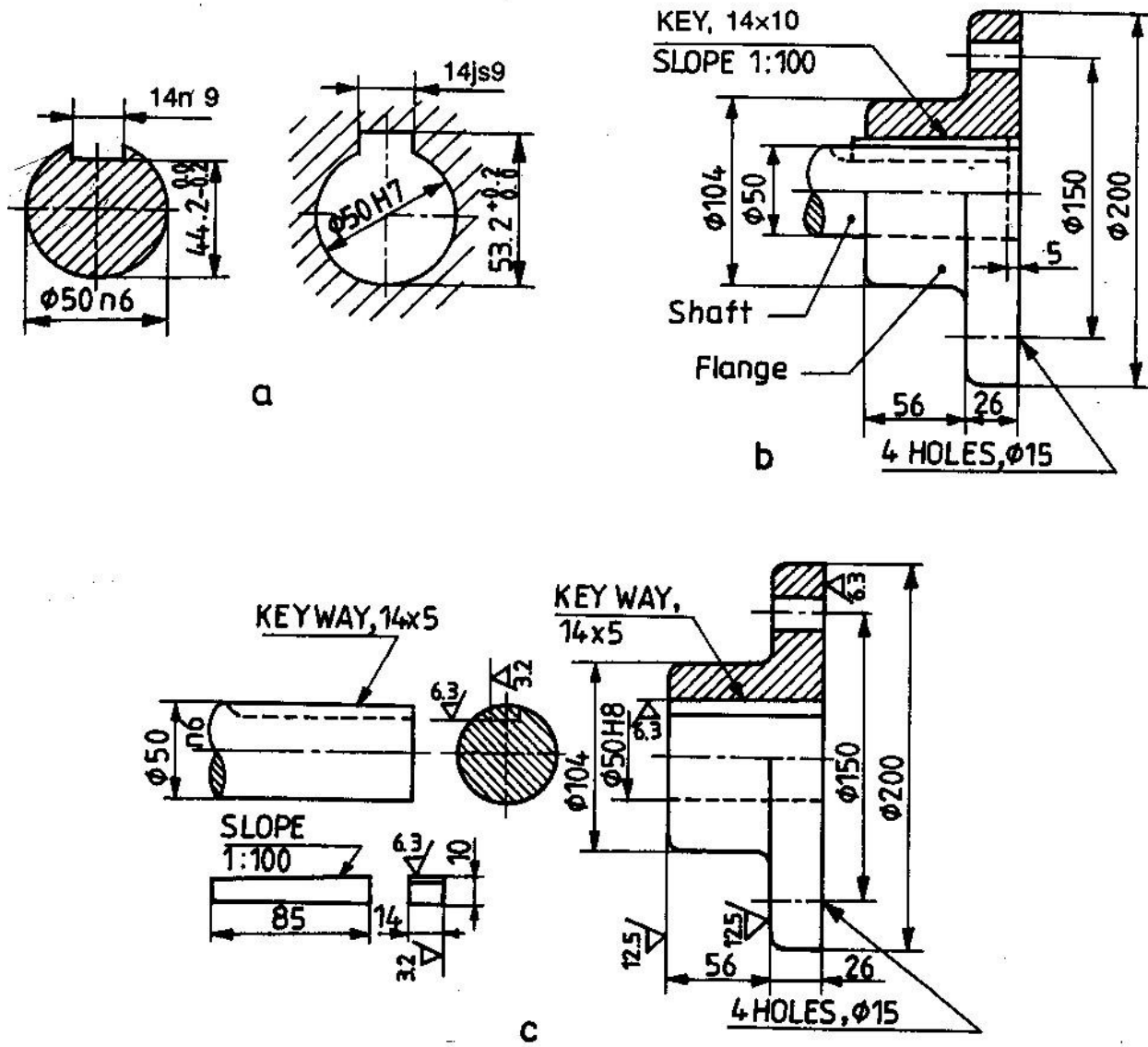
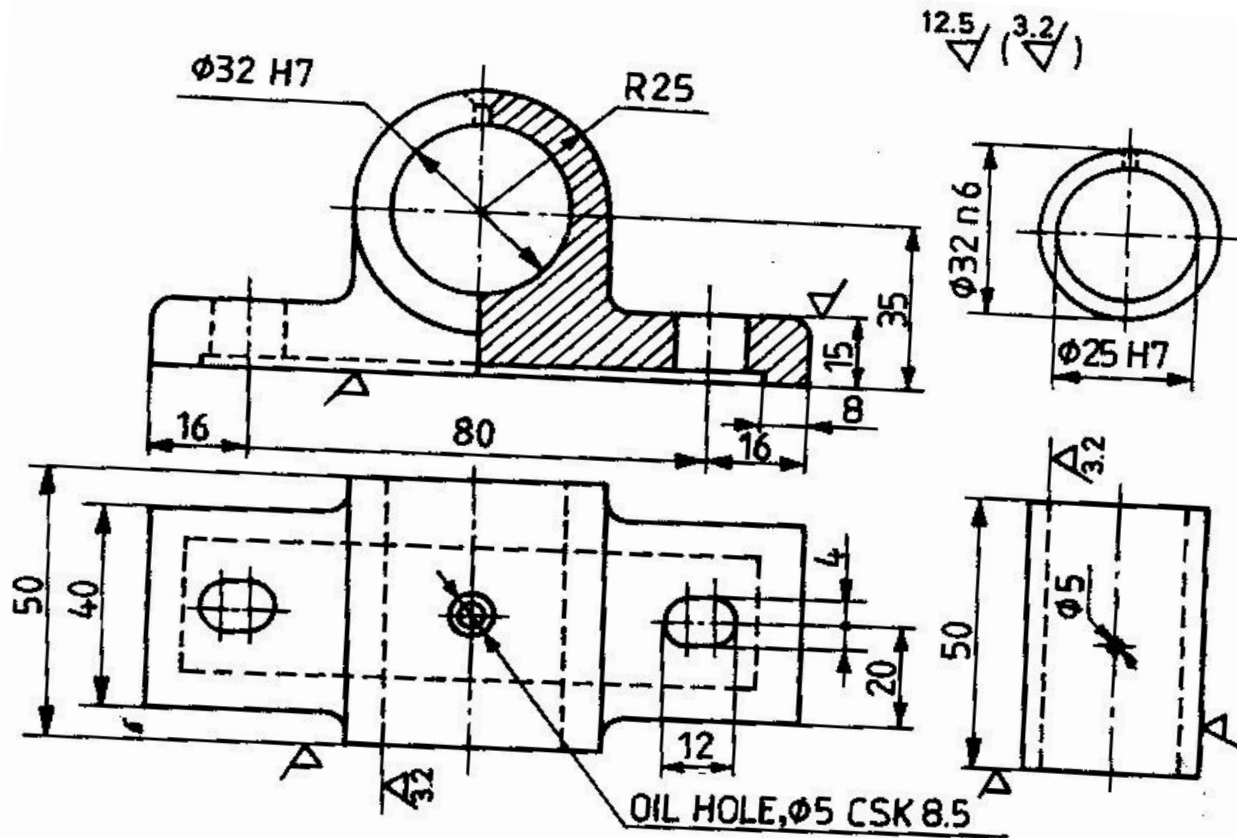


Fig. 8.2 Flange on shaft

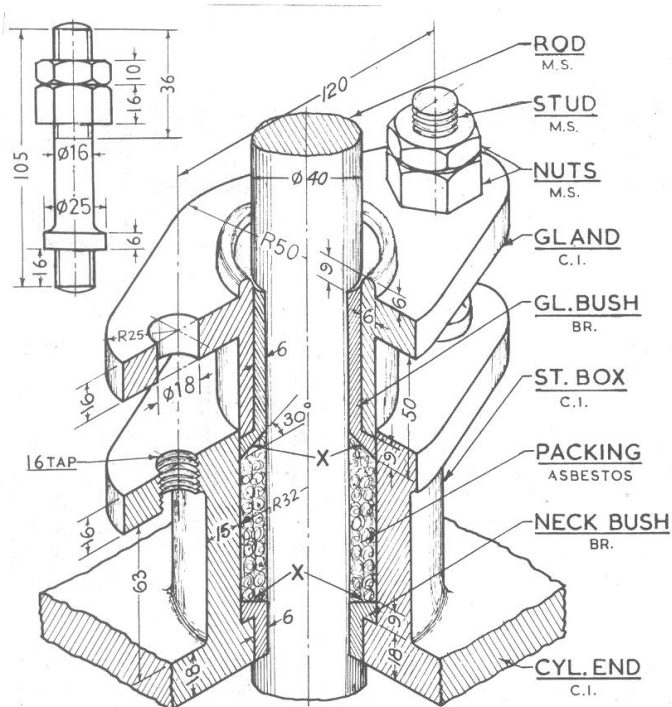


Tolerances

$\phi 32$ H7	-	32	$+0.025$	$+0.000$
$\phi 25$ H7	-	25	$+0.021$	$+0.000$
$\phi 32$ n6	-	32	$+0.033$	$+0.017$

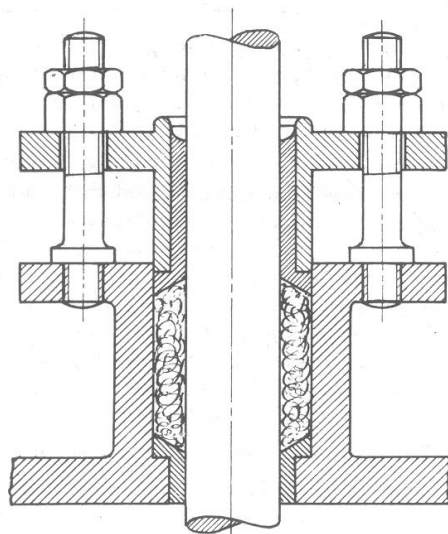
b

Fig. 8.7 Bush bearing

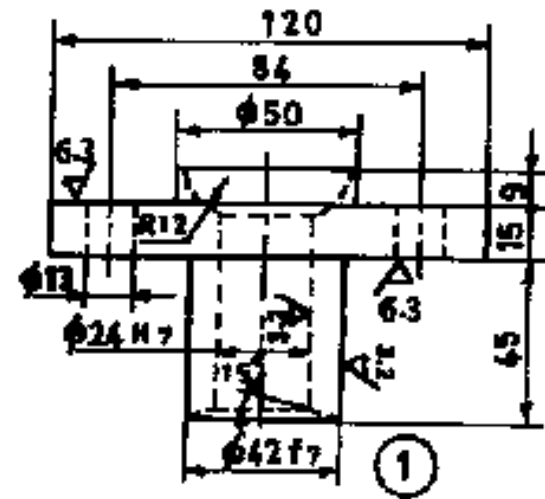
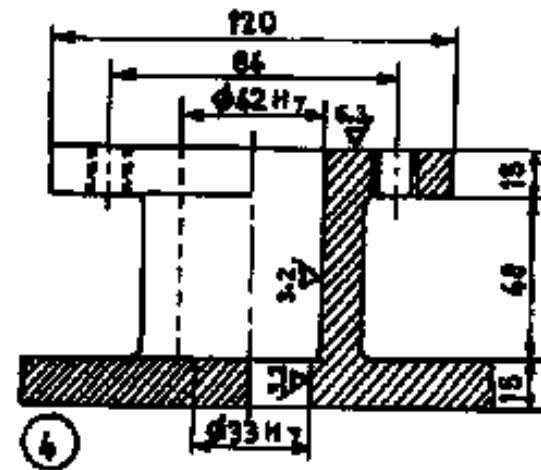
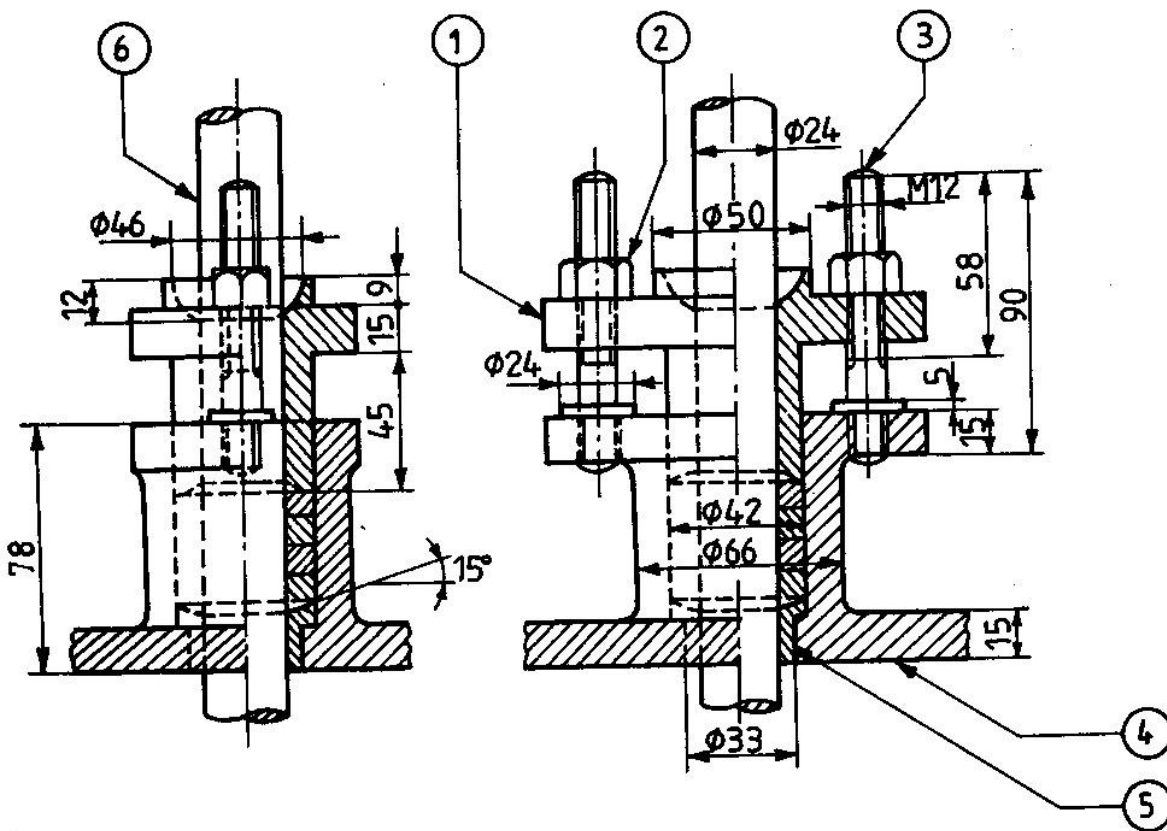


Stuffing box
FIG. 17-7

STUFFING BOX



Stuffing box
FIG. 17-8



Parts List

Part No.	Name	Matl.	Qty.
1	Gland	Brass	1
2	Nut, M12	MS	2
3	Stud	MS	2
4	Body	CI	1
5	Bush	Brass	1
6	Shaft	MS	1

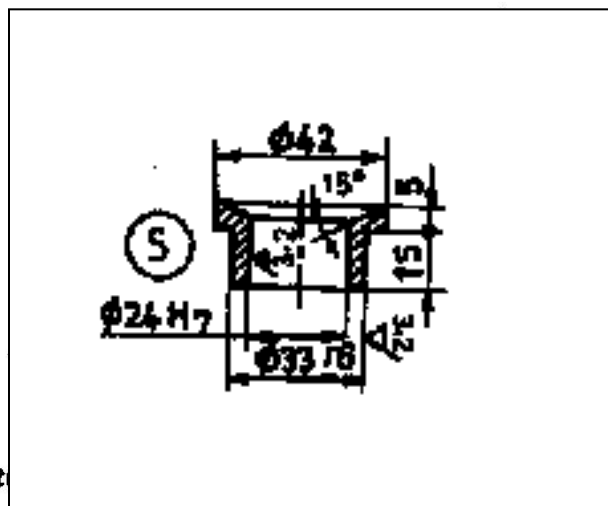


Fig. 9.12 St

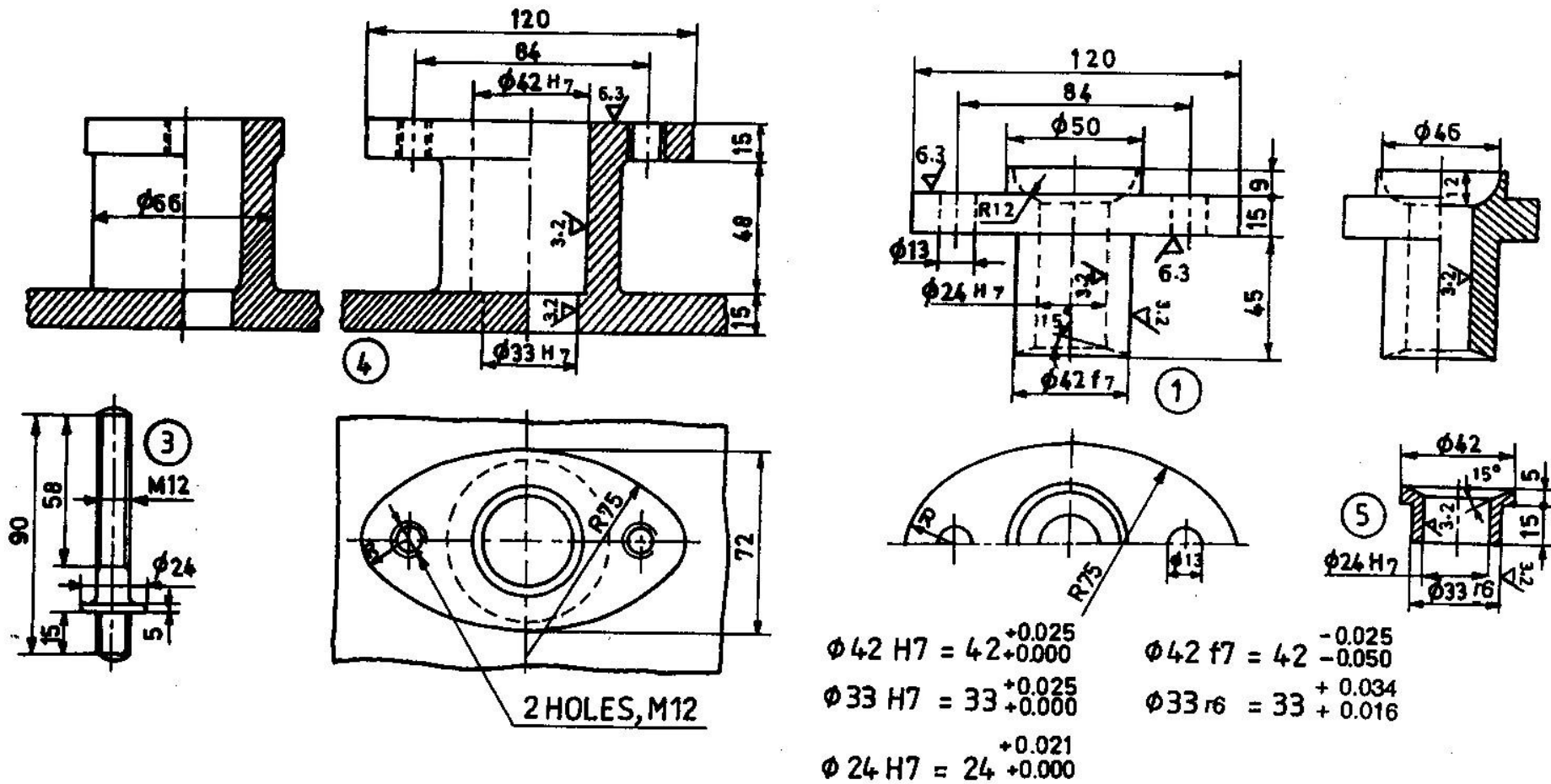


Fig. 9.13 Details of stuffing box

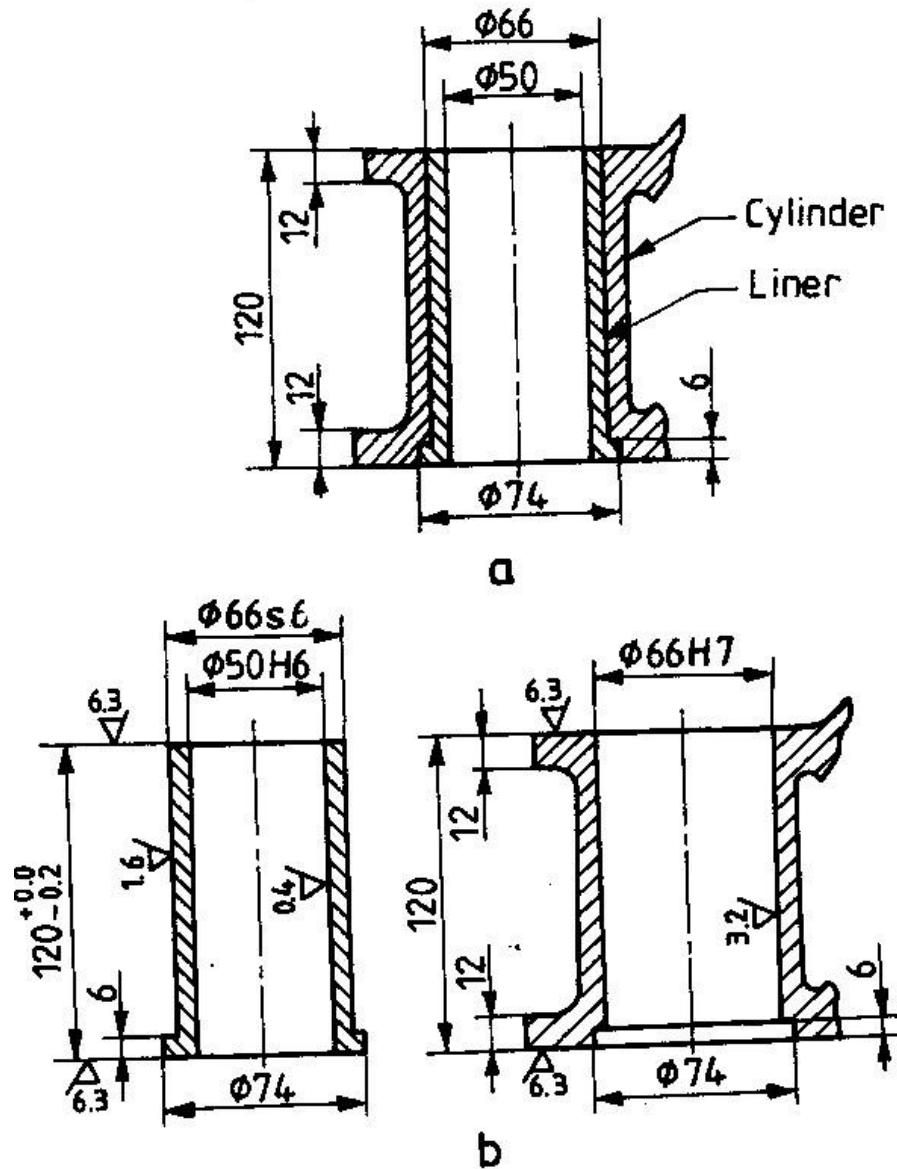


Fig. 8.6 Cylinder liner in block