

7. Bearing application

Locating bearings and non-locating bearings

Radial and axial loads in bearing units can be transmitted by locating and non-locating bearings.

A locating bearing is generally used for medium- and large-sized shafts that can reach high temperatures during operation. It has to support radially the shaft assembly and to locate it axially in both directions.

A non-locating bearing supports the shaft assembly only radially. It also allows axial displacement in relation to the housing to take place so that additional axial loading is avoided.

Axial displacement can take place either in the housing bore seating or in the bearing itself.

In case the shaft is supported by more than two bearings, only one of them will be a locating bearing and it will be the one with the lightest radial load.

In case of small-sized shafts, two non-locating bearings with limited displacement can be used. Each of them can accommodate axial loads in a single direction, having thus mutual location.

Fig. 7.1 shows a few of the most representative applications of locating and non-locating bearings, as follows:

a) The locating bearing is a single row deep groove ball bearing and the non-locating one is a cylindrical roller bearing with both rings tightly fitted on the shaft and into the housing, respectively.

b) Both bearings are supported by spherical roller bearings. The locating bearing is tightly fitted both on the shaft and into the housing. The non-locating bearing has the outer ring mounted with clearance into the housing and thus allows axial displacement in both directions.

c) The locating bearing consists of two tapered roller bearings, pair mounted and the non-locating bearing consists of one cylindrical roller bearing, NU type, tightly fitted into the housing bore.

d) The locating bearing consists of a cylindrical roller bearing, NUP type and the non-locating bearing consists of a cylindrical roller bearing, NU type.

e) The locating bearing consists of a cylindrical roller

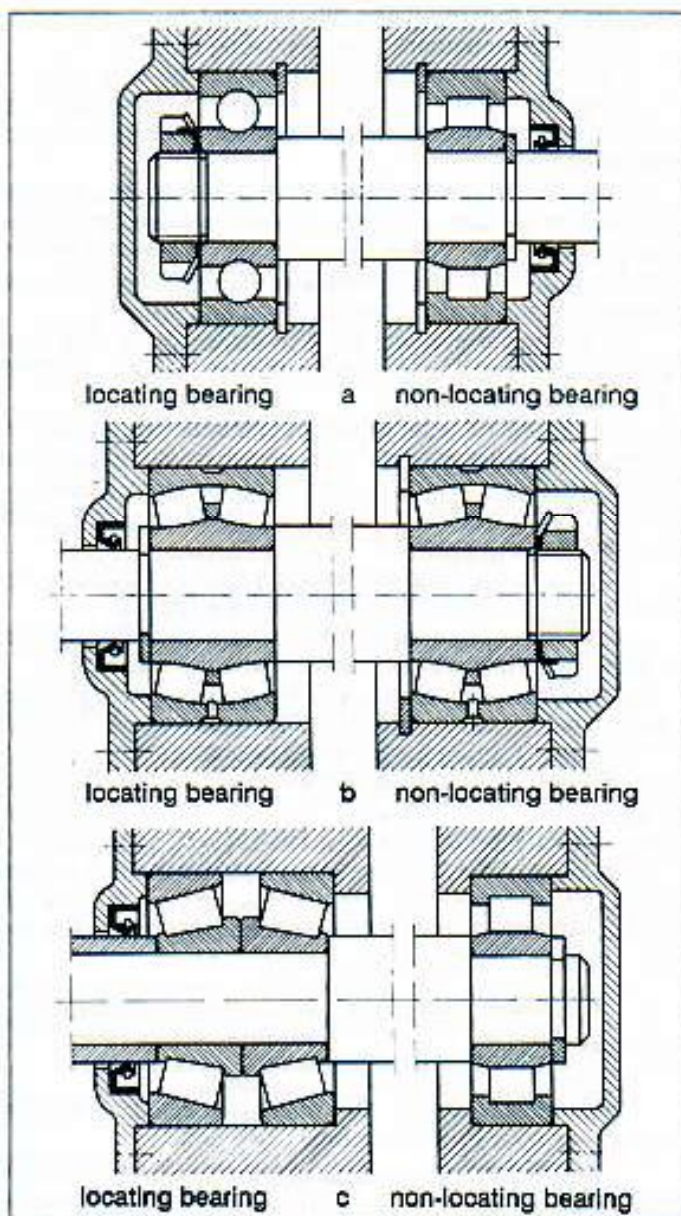


Fig. 7.1

bearing, NU type which takes over radial loads and of a four-point contact ball bearing (unloaded on the outside). The non-locating bearing consists of a cylindrical roller bearing, NU type.

f) The locating bearing consists of a needle roller bearing, NA type which takes over radial loads and of a single row deep groove ball bearing (unloaded on the outside) which takes over axial loads in both directions. The non-locating bearing consists of a needle roller bearing, NA type.

g) The shafts bearings can also be X-type arrangement of two tapered roller bearings which can be considered mutual located bearing.

Recommendation for bearing fit selection

Three main criteria have to be considered when selecting the bearing fit:

1. Firm location and uniform support of rings
2. Ease of mounting and dismounting
3. Axial displacement of non-locating bearing

The most common location is assured by a tight fit.

A high tightening is recommended for roller bearings and large-sized bearings in comparison to ball bearings of the same size.

In case of a tight fit, the inner ring is supported by the entire shaft contact surface, thus bearing is used at full load carrying capacity. When selecting the fit, one has to consider the difference of temperature which may occur between ring and shaft or between ring and housing.

The tolerance classes given in tables 7.1 and 7.3 are available for bearing fits which do not exceed +120 °C during operation.

As a general rule, the selection of the tolerance class "H" is recommended for bearings of separable design and tolerance class "J" for bearings of non-separable design.

When selecting a fit, the load of the rotating ring has to be considered, namely:

- If the inner ring rotates and the load is stationary, the outer ring should be mounted with clearance fit.
- If the inner ring rotates and the load is a rotating one, the outer ring should be mounted with tight fit.

- If the inner ring rotates and the direction of load is not determined, both rings should be mounted with tight fit.

In table 7.1, there are given recommendations to select the tolerance class for shaft as function of: bearing type, loading and shaft diameter. In table 7.3, one can find recommendations to select the tolerance class for housing.

Figure 7.2 shows schematically the tolerance classes for shaft and housing and their influence over fit type i.e. clearance, transition or tight fit for housing and transition fit or tight fit for shaft, respectively.

In tables 7.2 and 7.4, the deviations of the shaft diameter (7.2) and of the housing diameter (7.4) are given, considering the following:

- upper and lower limits
- theoretical minimum and maximum values of tightening (+) or clearance (-) in the fit
- the minimum and maximum values of the probable tightening or clearance in the fit (99% of fits are between

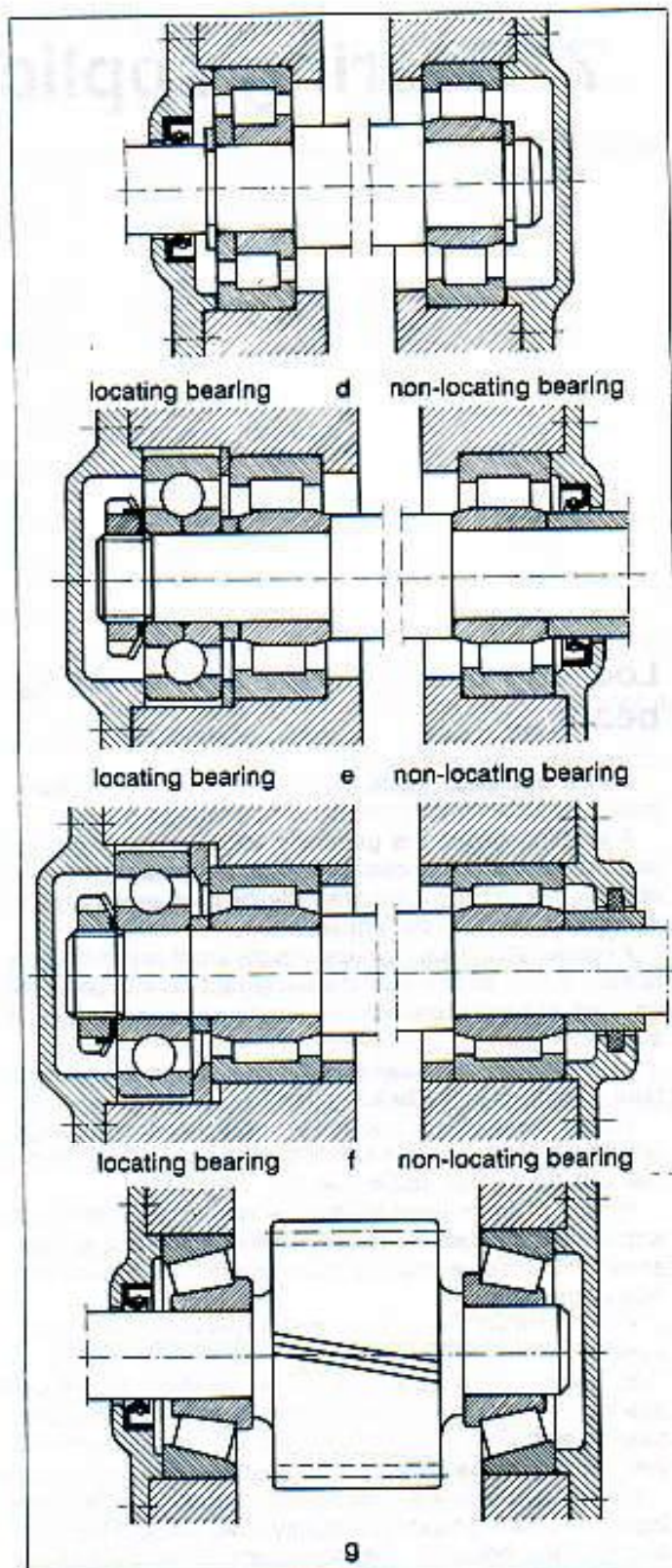


Fig. 7.1 (continued)

these limits)

The tolerances of bore diameter d_{mp} and outside diameter D_{mp} are valid for all metric sized bearings, except tapered roller bearings with $d < 30$ mm and $D < 150$ mm and thrust ball bearings with $D \leq 150$ mm (see table 5.15 and 5.16 on page 46 and table 5.31 and 5.32 on page 52).

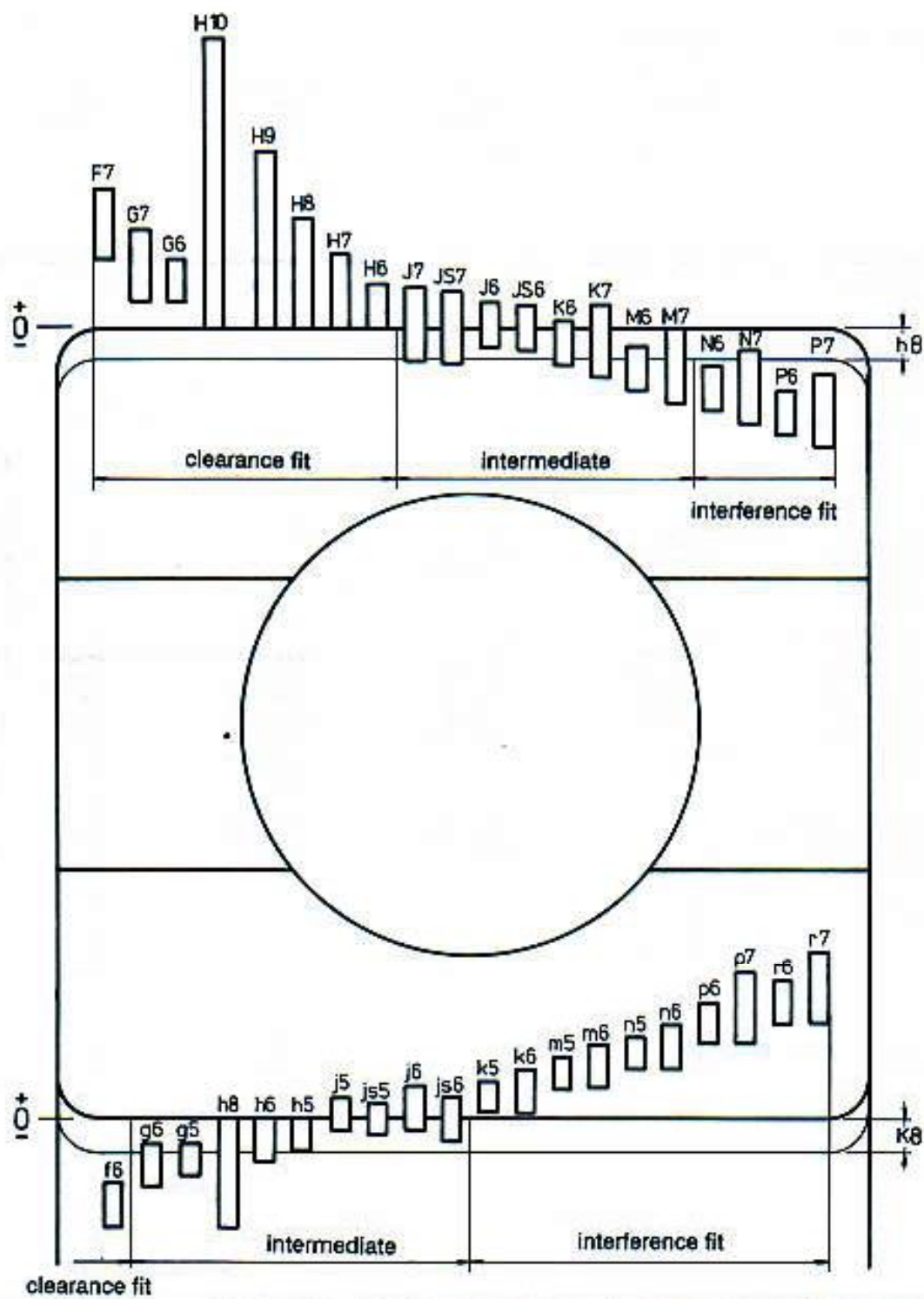


Fig.7.2

Bearings application

Tolerance classes for shafts

Table 7.1

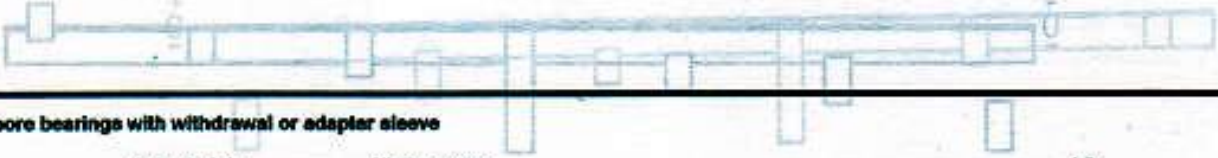
Operating conditions	Examples	Shaft diameter (mm)			Tolerance class symbol
		Ball bearings	Cylindrical, needle and tapered roller bearings	Spherical roller bearings	
Radial bearings with cylindrical bore					
Stationary inner ring load					
Easy axial displacement of inner ring on shaft desirable	Wheels on non-rotating shafts (free wheels)	All diameters			g8(f8)
Axial displacement of inner ring on shaft not necessary	Tension pulleys, sheaves				h6
Rotating inner ring load					
Light and variable loads (P < 0,06C)	Conveyors lightly loaded mechanisms, bearings	18...100 > 100...140	≤40 > 40...100	- -	j8 k6
Normal and heavy loads (P > 0,06C)	General mechanical engineering, electric motors, turbines, pumps, gearboxes, woodworking machines	≤18 > 18...100 > 100...140 > 140...200 > 200...280 - -	- ≤40 > 40...100 > 100...140 > 140...200 > 200...400 - -	- ≤40 > 40...65 > 65...100 > 100...140 > 140...280 > 280...500 > 500	j5 k5(k6) m5(m6) m6 n6 p6 r6 r7
Heavy loads and shock loads, arduous working conditions (P > 0,12C)	Heavy duty railway vehicles axle bearings, traction motors, rolling mills	- - -	> 50...140 > 140...200 > 200	> 50...100 > 100...200 > 200	n6 p6 r6
High running accuracy, light loads (P < 0,06C)	Machine tools	≤18 > 18...100 > 100...200 -	- ≤40 > 40...140 > 140...200	- - - -	h5 j5 k5 m5
Axial loads					
	All kind of bearing application	≤250 > 250	≤250 > 250	< 250 > 250	j6 js6

Bearings application

Tolerance classes for shafts

Bearings application
 shaft fit

Table 7.1 (continued)

Operating conditions	Examples	Shaft diameter (mm)	Tolerance class symbol
			
Tapered bore bearings with withdrawal or adapter sleeve			
	Axle shaft for railway vehicles	All diameters	h9
	General mechanical engineering		h10
Thrust bearings			
Axial loads			
Thrust ball bearings		All sizes	h8
Cylindrical and needle roller thrust bearings		All sizes	h8(h8)
Cylindrical, needle roller and cage thrust assembly		All sizes	h8
Combined loads on spherical roller thrust bearings			
Stationary load on shaft washer		≤250 >250	j8 js8
Rotating load on shaft washer or indeterminate load direction		≤200 >200...400 >400	k8 m8 n8

Bearings application

Shaft fits

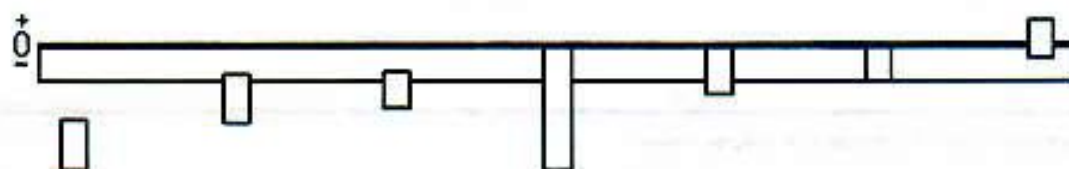


Table 7.2

Shaft Diameter		Bearing Bore diameter tolerance Δdmp		Deviations of shaft diameter, resultant fits Tolerances														
d	*			f6	g6	g5	h6	h6	h5	j5								
nominal				a) Deviations (shaft diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance														
over	up to	low	high															
mm		μm																
1	3	-8	0	a) -6 b) +2 c) 0	-12 -12 -10	-2 +6 +4	-8 -8 -6	-2 +6 +5	-8 -8 -5	0 +8 +8	-14 -14 -12	0 +8 +8	-8 -8 -4	0 +8 +7	-4 -4 -3	+2 +10 +9	-2 -2 -1	
3	6	-8	0	-10 -2 -4	-18 -18 -18	-4 +4 +2	-12 -12 -10	-4 +4 +3	-8 -9 -8	0 +8 +5	-18 -18 -15	0 +8 +8	-8 -8 -8	0 +8 +7	-5 -5 -4	+3 +11 +10	-2 -2 -1	
6	10	-8	0	-13 -5 -7	-22 -22 -20	-5 +3 +1	-14 -14 -12	-5 +3 +1	-11 -11 -9	0 +8 +5	-22 -22 -19	0 +8 +8	-8 -8 -7	0 +8 +6	-6 -6 -4	+4 +12 +10	-2 -2 0	
10	18	-8	0	-16 -8 -10	-27 -27 -25	-6 +2 0	-17 -17 -15	-6 +2 0	-14 -14 -12	0 +8 +5	-27 -27 -24	0 +8 +8	-11 -11 -8	0 +8 +6	-8 -8 -6	+5 +13 +11	-3 -3 -1	
18	30	-10	0	-20 -10 -13	-33 -33 -30	-7 +3 0	-20 -20 -17	-7 +3 +1	-16 -16 -14	0 +10 +8	-33 -33 -29	0 +10 +7	-13 -13 -10	0 +10 +8	-9 -9 -7	+5 +15 +13	-4 -4 -2	
30	50	-12	0	-25 -13 -17	-41 -41 -37	-9 +3 -1	-25 -25 -21	-9 +3 0	-20 -20 -17	0 +12 +7	-39 -39 -34	0 +12 +8	-16 -16 -12	0 +12 +8	-11 -11 -8	+6 +18 +15	-5 -5 -2	
50	80	-15	0	-30 -15 -18	-49 -49 -45	-10 +5 +1	-29 -29 -25	-10 +5 +1	-23 -23 -19	0 +15 +9	-46 -46 -40	0 +15 +11	-19 -19 -15	0 +15 +11	-13 -13 -9	+8 +21 +17	-7 -7 -3	
80	120	-20	0	-38 -18 -22	-58 -58 -52	-12 +8 +2	-34 -34 -28	-12 +8 +3	-27 -27 -22	0 +20 +12	-54 -54 -48	0 +20 +14	-22 -22 -16	0 +20 +15	-15 -15 -10	+6 +26 +21	-8 -8 -4	
120	180	-25	0	-43 -18 -25	-68 -68 -61	-14 +11 +4	-38 -38 -32	-14 +11 +5	-32 -32 -26	0 +25 +15	-63 -63 -53	0 +25 +18	-25 -25 -18	0 +25 +19	-18 -18 -12	+7 +32 +26	-11 -11 -5	
180	250	-30	0	-50 -20 -28	-79 -79 -71	-15 +15 +7	-44 -44 -36	-15 +15 +9	-35 -35 -29	0 +30 +18	-72 -72 -60	0 +30 +22	-29 -29 -21	0 +30 +24	-20 -20 -14	+7 +37 +31	-13 -13 -7	
250	315	-35	0	-58 -21 -30	-88 -88 -79	-17 +18 +8	-48 -48 -40	-17 +18 +10	-40 -40 -32	0 +35 +22	-81 -81 -68	0 +35 +26	-32 -32 -23	0 +35 +27	-23 -23 -15	+7 +42 +34	-16 -16 -8	
315	400	-40	0	-62 -22 -33	-98 -98 -87	-18 +22 +11	-54 -54 -43	-18 +22 +14	-43 -43 -35	0 +40 +25	-89 -89 -74	0 +40 +29	-36 -36 -25	0 +40 +32	-25 -25 -17	+7 +47 +39	-18 -18 -10	
400	500	-45	0	-68 -23 -35	-108 -108 -96	-20 +25 +13	-60 -60 -48	-20 +25 +16	-47 -47 -38	0 +45 +28	-97 -97 -80	0 +45 +33	-40 -40 -28	0 +45 +36	-27 -27 -18	+7 +52 +43	-20 -20 -11	

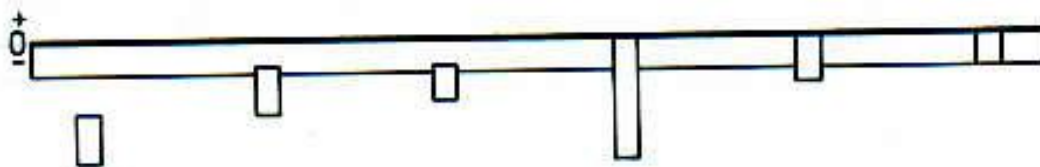


Table 7.2 (continued)

Shaft Diameter		Bearing Bore diameter tolerance Δdmp		Deviations of shaft diameter, resultant fits Tolerances											
d				f6		g6		g5		h6		h6		h5	
nominal				a) Deviations (shaft diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance											
over	up to	low	high												
mm		μm													
500	630	-50	0	a) -78 b) -26 c) -39	-120 -120 -107	-22 +28 +15	-68 -68 -53	-22 +28 +18	-50 -50 -40	0 +50 +31	-110 -110 -91	0 +50 +37	-44 -44 -31	0 +50 +40	-28 -28 -18
630	800	-75	0	-90 -5 -22	-130 -130 -113	-24 +51 +34	-74 -74 -57	-24 +51 +39	-56 -56 -44	0 +75 +48	-125 -125 -98	0 +75 +58	-50 -50 -33	0 +75 +83	-32 -32 -20
800	1 000	-100	0	-88 +14 -6	-142 -142 -122	-28 +74 +54	-82 -82 -82	-28 +74 +60	-62 -62 -48	0 +100 +67	-140 -140 -107	0 +100 +80	-56 -56 -36	0 +100 +88	-36 -36 -22
1 000	1 250	-125	0	-98 +27 +3	-184 -184 -140	-28 +97 +73	-94 -94 -70	-28 +97 +80	-70 -70 -53	0 +125 +84	-165 -165 -124	0 +125 +101	-66 -66 -42	0 +125 +108	-42 -42 -25
1 250	1 600	-160	0	-110 +50 +20	-188 -188 -158	-30 +130 +100	-108 -108 -78	-30 +130 +108	-80 -80 -59	0 +160 +108	-185 -185 -144	0 +160 +130	-78 -78 -48	0 +160 +138	-50 -50 -29
1 600	2 000	-200	0	-120 +80 +45	-212 -212 -177	-32 +168 +133	-124 -124 -89	-32 +168 +143	-82 -82 -67	0 +200 +138	-230 -230 -188	0 +200 +185	-82 -82 -57	0 +200 +175	-60 -60 -35

Bearings application

Shaft fits

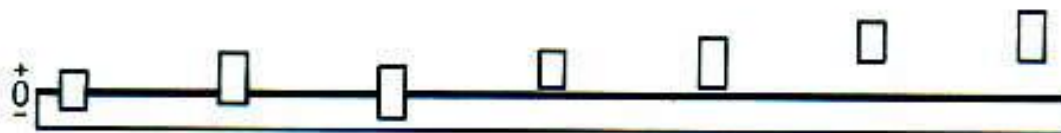


Table 7.2 (continued)

Shaft Diameter		Bearing Bore diameter tolerance Δdmp		Deviations of shaft diameter, resultant fits Tolerances														
d				js5	js	js6	k5	k6	m5	m6								
nominal				a) Deviations (shaft diameter)														
over	up to	low	high	b) Tightening/Theoretical clearance														
				c) Tightening/Probable clearance														
mm		μm																
1	3	-8	0	a) +2	-2	+4	-2	+3	-3	+4	0	+8	0	+6	+2	+8	+2	
				b) +10	-2	+12	-2	+11	-3	+12	0	+14	0	+14	+2	+16	+2	
				c) +9	-1	+10	0	+8	-1	+11	+1	+12	+2	+13	+3	+14	+4	
3	6	-8	0	+2,5	-2,5	+6	-2	+4	-4	+6	+1	+9	+1	+9	+4	+12	+4	
				+10,5	-2,5	+14	-2	+12	-4	+14	+1	+17	+1	+17	+4	+20	+4	
				+8	-1	+12	0	+10	-2	+13	+2	+15	+3	+16	+5	+18	+6	
6	10	-8	0	+3	-3	+7	-2	+4,5	-4,5	+7	+1	+10	+1	+12	+6	+15	+6	
				+11	-3	+15	-2	+12,5	-4,5	+15	+1	+18	+1	+20	+6	+23	+6	
				+9	-1	+13	0	+11	-3	+13	+3	+16	+3	+18	+8	+21	+8	
10	18	-8	0	+4	-4	+8	-3	+5,5	-5,5	+9	+1	+12	+1	+15	+7	+18	+7	
				+12	-4	+16	-3	+13,5	-5,5	+17	+1	+20	+1	+23	+7	+26	+7	
				+10	-2	+14	-1	+11	-3	+15	+3	+18	+3	+21	+8	+24	+9	
18	30	-10	0	+4,5	-4,5	+9	-4	+6,5	-8,5	+11	+2	+15	+2	+17	+8	+21	+8	
				+14,5	-4,5	+19	-4	+16,5	-8,5	+21	+2	+25	+2	+27	+8	+31	+8	
				+12	-2	+16	-1	+14	-4	+19	+4	+22	+5	+25	+10	+28	+11	
30	50	-12	0	+5,5	-5,5	+11	-5	+8	-8	+13	+2	+16	+2	+20	+9	+25	+9	
				+17,5	-5,5	+23	-5	+20	-8	+25	+2	+30	+2	+32	+9	+37	+9	
				+15	-3	+19	-1	+16	-4	+22	+5	+26	+6	+29	+12	+33	+13	
50	80	-15	0	+6,5	-6,5	+12	-7	+9,5	-9,5	+15	+2	+21	+2	+24	+11	+30	+11	
				+21,5	-6,5	+27	-7	+24,5	-9,5	+30	+2	+36	+2	+38	+11	+45	+11	
				+18	-3	+23	-3	+20	-5	+26	+6	+32	+6	+35	+15	+41	+15	
80	120	-20	0	+7,5	-7,5	+13	-8	+11	-11	+18	+3	+25	+3	+28	+13	+35	+13	
				+27,5	-7,5	+33	-8	+31	-11	+38	+3	+45	+3	+48	+13	+55	+13	
				+23	-3	+27	-3	+25	-5	+33	+8	+39	+9	+43	+16	+49	+18	
120	180	-25	0	+9	-9	+14	-11	+12,5	-12,5	+21	+3	+28	+3	+33	+15	+40	+15	
				+34	-9	+39	-11	+37,5	-12,5	+46	+3	+53	+3	+58	+15	+65	+15	
				+28	-3	+32	-4	+31	-6	+40	+9	+46	+10	+52	+21	+58	+22	
180	250	-30	0	+10	-10	+16	-13	+14,5	-14,5	+24	+4	+33	+4	+37	+17	+48	+17	
				+40	-10	+46	-13	+44,5	-14,5	+54	+4	+63	+4	+67	+17	+76	+17	
				+34	-4	+38	-5	+36	-6	+46	+10	+55	+12	+61	+23	+68	+25	
250	315	-35	0	+11,5	-11,5	+18	-16	+16	-16	+27	+4	+38	+4	+43	+20	+52	+20	
				+46,5	-11,5	+51	-16	+51	-18	+62	+4	+71	+4	+78	+20	+87	+20	
				+39	-4	+42	-7	+42	-7	+54	+12	+62	+13	+70	+28	+78	+29	
315	400	-40	0	+12,5	-12,5	+18	-18	+18	-18	+29	+4	+40	+4	+46	+21	+57	+21	
				+52,5	-12,5	+58	-18	+58	-18	+69	+4	+80	+4	+86	+21	+97	+21	
				+44	-4	+47	-7	+47	-7	+61	+12	+69	+15	+78	+29	+88	+32	
400	500	-45	0	+13,5	-13,5	+20	-20	+20	-20	+32	+5	+45	+5	+50	+23	+63	+23	
				+58,5	-13,5	+65	-20	+65	-20	+77	+5	+90	+5	+95	+23	+108	+23	
				+49	-4	+53	-8	+53	-8	+68	+14	+76	+17	+86	+32	+96	+35	

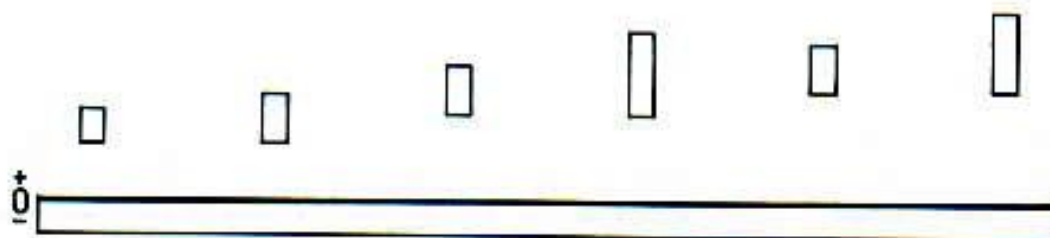


Table 7.2 (continued)

Shaft Diameter		Bearing Bore diameter tolerance Δdmp		Deviations of shaft diameter, resultant fits Tolerances													
d				js5		js6		js6		k5		k6		m5		m6	
nominal				a) Deviations (shaft diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance													
over	up to	low	high														
mm		μm															
500	630	-50	0	a) +14	-14	+22	-22	+22	-22	+29	0	+44	0	+55	+26	+70	+26
				b) +64	-14	+72	-22	+72	-22	+78	0	+94	0	+104	+26	+120	+26
				c) +54	-4	+58	-9	+58	-9	+88	+10	+81	+13	+94	+36	+107	+39
630	800	-75	0	+18	-16	+25	-25	+25	-25	+32	0	+50	0	+82	+30	+90	+30
				+91	-16	+100	-25	+100	-25	+107	0	+125	0	+137	+30	+155	+30
				+79	-4	+83	-8	+83	-8	+95	+12	+108	+17	+125	+42	+138	+47
800	1 000	-100	0	+18	-18	+28	-28	+28	-28	+38	0	+58	0	+70	+34	+90	+34
				+118	-18	+128	-28	+128	-28	+138	0	+158	0	+170	+34	+190	+34
				+104	-4	+108	-8	+108	-8	+122	+14	+138	+20	+158	+48	+170	+54
1 000	1 250	-125	0	+21	-21	+33	-33	+33	-33	+42	0	+86	0	+82	+40	+106	+40
				+146	-21	+158	-33	+158	-33	+167	0	+191	0	+207	+40	+231	+40
				+129	-4	+134	-9	+134	-9	+150	+17	+167	+24	+190	+57	+207	+64
1 250	1 600	-160	0	+25	-25	+39	-39	+39	-39	+50	0	+78	0	+98	+48	+126	+48
				+185	-25	+199	-39	+199	-39	+210	0	+238	0	+258	+48	+296	+48
				+164	-4	+169	-9	+169	-9	+188	+21	+208	+30	+237	+68	+256	+78
1 600	2 000	-200	0	+30	-30	+48	-48	+48	-48	+80	0	+82	0	+118	+58	+150	+58
				+230	-30	+246	-48	+246	-48	+260	0	+292	0	+318	+58	+350	+58
				+205	-5	+211	-11	+211	-11	+235	+25	+257	+35	+293	+83	+315	+93

Bearings application

Shaft fits



Tabelul 7.2 (continued)

Shaft Diameter		Bearing Bore diameter tolerance Δd_{mp}		Deviations of shaft diameter, resultant fits Tolerances											
d				n5		n6		p6		p7		r6		r7	
nominal				a) Deviations (shaft diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance											
over	up to	low	high												
mm		μm													
1	3	-8	0	a) +8 b) +18 c) +15	+4 +4 +5	+10 +18 +18	+4 +4 +6	+12 +20 +18	+6 +8 +8	+18 +24 +22	+8 +8 +8	+16 +24 +22	+10 +10 +12	+20 +28 +28	+10 +10 +12
3	6	-8	0	+13 +21 +20	+8 +8 +8	+16 +24 +22	+8 +8 +10	+20 +28 +26	+12 +12 +14	+24 +32 +30	+12 +12 +14	+23 +31 +29	+15 +15 +17	+27 +35 +33	+15 +15 +17
6	10	-8	0	+16 +24 +22	+10 +10 +12	+18 +27 +25	+10 +10 +12	+24 +32 +30	+15 +15 +17	+30 +38 +35	+15 +15 +18	+28 +36 +34	+18 +18 +21	+34 +42 +39	+18 +19 +22
10	18	-8	0	+20 +28 +26	+12 +12 +14	+23 +31 +29	+12 +12 +14	+29 +37 +35	+18 +18 +20	+36 +44 +41	+18 +18 +21	+34 +42 +40	+23 +23 +25	+41 +48 +48	+23 +23 +26
18	30	-10	0	+24 +34 +32	+15 +15 +17	+28 +38 +35	+15 +15 +18	+35 +45 +42	+22 +22 +25	+43 +53 +50	+22 +22 +25	+41 +51 +48	+28 +28 +31	+48 +58 +58	+28 +28 +31
30	50	-12	0	+28 +40 +37	+17 +17 +20	+33 +45 +41	+17 +17 +21	+42 +54 +50	+26 +26 +30	+51 +63 +59	+26 +26 +30	+50 +62 +58	+34 +34 +38	+59 +71 +67	+34 +34 +38
50	65	-15	0	+33 +48 +44	+20 +20 +24	+38 +54 +50	+20 +20 +24	+51 +66 +62	+32 +32 +36	+62 +77 +72	+32 +32 +37	+60 +75 +71	+41 +41 +45	+71 +86 +81	+41 +41 +46
65	90	-15	0	+33 +48 +44	+20 +20 +24	+38 +54 +50	+20 +20 +24	+51 +66 +62	+32 +32 +36	+62 +77 +72	+32 +32 +37	+62 +77 +73	+43 +43 +47	+73 +88 +83	+43 +43 +48
90	100	-20	0	+38 +58 +53	+23 +23 +28	+45 +65 +59	+23 +23 +29	+59 +79 +73	+37 +37 +43	+72 +82 +85	+37 +37 +44	+73 +83 +87	+51 +51 +57	+88 +108 +98	+51 +51 +58
100	120	-20	0	+38 +58 +53	+23 +23 +28	+45 +65 +59	+23 +23 +29	+59 +79 +73	+37 +37 +43	+72 +82 +85	+37 +37 +44	+76 +88 +90	+54 +54 +60	+88 +109 +102	+54 +54 +61
120	140	-25	0	+45 +70 +64	+27 +27 +33	+52 +77 +70	+27 +27 +34	+68 +83 +86	+43 +43 +50	+83 +108 +100	+43 +43 +51	+88 +113 +108	+63 +63 +70	+103 +128 +120	+63 +63 +71
140	160	-25	0	+45 +70 +64	+27 +27 +33	+52 +77 +70	+27 +27 +34	+68 +83 +86	+43 +43 +50	+83 +108 +100	+43 +43 +51	+90 +115 +108	+85 +85 +72	+105 +130 +122	+85 +85 +73
160	180	-25	0	+45 +70 +64	+27 +27 +33	+52 +77 +70	+27 +27 +34	+68 +83 +86	+43 +43 +50	+83 +108 +100	+43 +43 +51	+93 +118 +111	+88 +88 +75	+108 +133 +125	+68 +68 +76

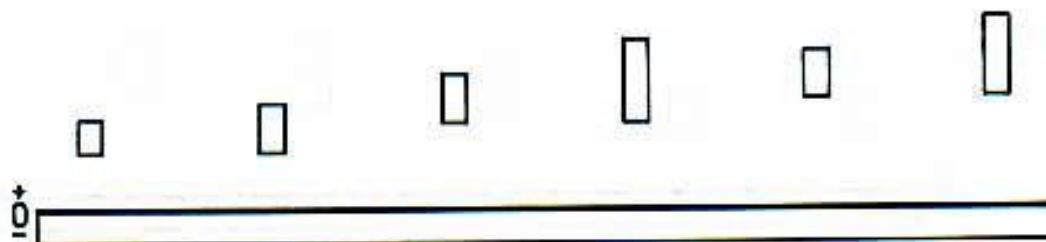


Table 7.2 (continued)

Shaft Diameter		Bearing Bore diameter tolerance Δdmp		Deviations of shaft diameter, resultant fits Tolerances											
d				n5	n6	p6	p7	r6	r7						
nominal				a) Deviations (shaft diameter)	b) Tightening/Theoretical clearance	c) Tightening/Probable clearance									
over	up to	low	high												
mm															
180	200	-30	0	a) +51 b) +81 c) +75	+31 +31 +37	+60 +90 +82	+31 +31 +39	+79 +109 +101	+50 +50 +58	+98 +128 +116	+50 +50 +60	+108 +138 +128	+77 +77 +85	+123 +153 +143	+77 +77 +87
200	225	-30	0	+51 +81 +75	+31 +31 +37	+60 +90 +82	+31 +31 +39	+79 +109 +101	+50 +50 +58	+98 +128 +116	+50 +50 +60	+108 +138 +131	+80 +80 +88	+126 +156 +148	+80 +80 +90
225	250	-30	0	+51 +81 +75	+31 +31 +37	+60 +90 +82	+31 +31 +39	+79 +109 +101	+50 +50 +58	+98 +128 +116	+50 +50 +60	+113 +143 +135	+84 +84 +82	+130 +160 +150	+84 +84 +94
250	280	-35	0	+57 +82 +84	+34 +34 +42	+66 +101 +82	+34 +34 +43	+88 +123 +114	+56 +56 +65	+108 +143 +131	+56 +56 +68	+126 +161 +152	+94 +94 +103	+146 +181 +169	+94 +94 +108
280	315	-35	0	+57 +82 +84	+34 +34 +42	+66 +101 +82	+34 +34 +43	+88 +123 +114	+56 +56 +85	+108 +143 +131	+56 +56 +68	+130 +165 +156	+88 +88 +107	+150 +185 +173	+88 +88 +110
315	355	-40	0	+62 +102 +94	+37 +37 +45	+73 +113 +102	+37 +37 +48	+98 +138 +127	+62 +62 +73	+118 +159 +146	+82 +82 +75	+144 +184 +173	+108 +108 +119	+185 +205 +192	+108 +108 +121
355	400	-40	0	+62 +102 +94	+37 +37 +45	+73 +113 +102	+37 +37 +48	+98 +138 +127	+62 +62 +73	+118 +159 +146	+82 +82 +75	+150 +180 +178	+114 +114 +125	+171 +211 +188	+114 +114 +127
400	450	-45	0	+67 +112 +103	+40 +40 +49	+80 +125 +113	+40 +40 +52	+108 +153 +141	+68 +68 +80	+131 +178 +161	+68 +68 +83	+168 +211 +199	+128 +128 +138	+189 +234 +219	+128 +128 +141
450	500	-45	0	+67 +112 +103	+40 +40 +49	+80 +125 +113	+40 +40 +52	+108 +153 +141	+68 +68 +80	+131 +178 +161	+68 +68 +83	+172 +217 +205	+132 +132 +144	+195 +240 +225	+132 +132 +147
500	560	-50	0	+73 +122 +112	+44 +44 +54	+88 +139 +125	+44 +44 +57	+122 +172 +159	+78 +78 +91	+148 +188 +182	+78 +78 +94	+184 +244 +231	+150 +150 +163	+220 +270 +254	+150 +150 +166
560	630	-50	0	+73 +122 +112	+44 +44 +54	+88 +138 +125	+44 +44 +57	+122 +172 +159	+78 +78 +91	+148 +188 +182	+78 +78 +94	+196 +249 +236	+155 +155 +168	+225 +275 +259	+155 +155 +171
630	710	-75	0	+82 +157 +145	+50 +50 +62	+100 +175 +158	+50 +50 +67	+138 +213 +198	+88 +88 +105	+168 +243 +221	+88 +88 +110	+225 +300 +283	+175 +175 +182	+255 +330 +308	+175 +175 +187
710	800	-75	0	+82 +157 +145	+50 +50 +62	+100 +175 +158	+50 +50 +67	+138 +213 +198	+88 +88 +105	+168 +243 +221	+88 +88 +110	+235 +310 +293	+185 +185 +202	+265 +340 +318	+185 +185 +207

Bearings application

Shaft fits

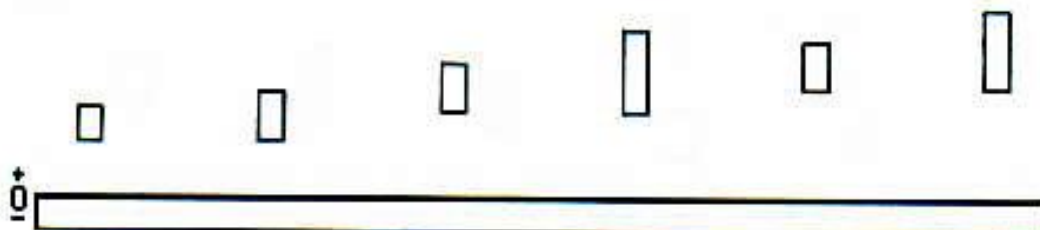
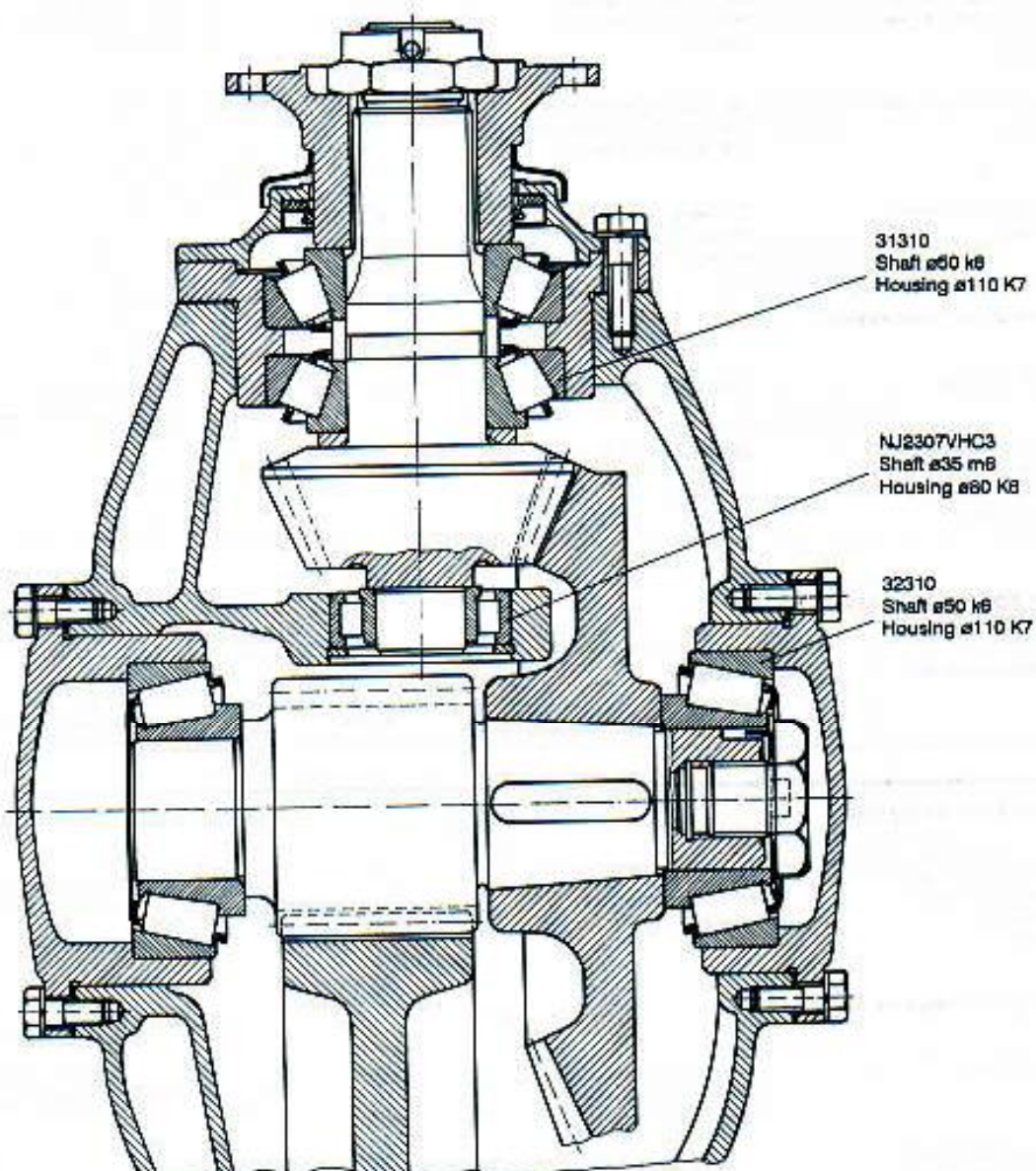


Table 7.2 (continued)

Shaft Diameter		Bearing Bore diameter tolerance Δ_{dmp}		Deviations of shaft diameter, resultant fits Tolerances												
d				n5	n6	p6	p7	r6	r7							
nominal				a) Deviations (shaft diameter)												
over up to				b) Tightening/Theoretical clearance												
				c) Tightening/Probable clearance												
mm		μm														
800	900	-100	0	a) +92 b) +182 c) +178	+56 +56 +70	+112 +212 +192	+56 +56 +76	+156 +256 +236	+100 +100 +120	+180 +290 +263	+100 +100 +127	+266 +366 +346	+210 +210 +230	+300 +400 +373	+210 +210 +237	
900	1 000	-100	0	+82 +182 +178	+56 +56 +70	+112 +212 +192	+56 +56 +76	+156 +256 +236	+100 +100 +120	+180 +290 +263	+100 +100 +127	+276 +376 +356	+220 +220 +240	+310 +410 +383	+220 +220 +247	
1 000	1 120	-125	0	+108 +233 +218	+66 +66 +83	+132 +257 +233	+66 +66 +80	+186 +311 +287	+120 +120 +144	+225 +350 +317	+120 +120 +153	+326 +441 +417	+250 +250 +274	+355 +480 +447	+250 +250 +283	
1 120	1 250	-125	0	+108 +233 +216	+66 +66 +83	+132 +257 +233	+66 +66 +90	+186 +311 +287	+120 +120 +144	+225 +350 +317	+120 +120 +153	+326 +451 +427	+260 +260 +284	+365 +490 +457	+260 +260 +283	
1 250	1 400	-160	0	+126 +288 +267	+78 +78 +99	+156 +316 +286	+78 +78 +108	+216 +376 +346	+140 +140 +170	+265 +425 +385	+140 +140 +180	+376 +538 +508	+300 +300 +330	+425 +585 +545	+300 +300 +340	
1 400	1 600	-160	0	+126 +288 +267	+78 +78 +99	+156 +316 +286	+78 +78 +108	+216 +376 +346	+140 +140 +170	+265 +425 +385	+140 +140 +180	+408 +568 +538	+330 +330 +360	+455 +615 +575	+330 +330 +370	
1 600	1 800	-200	0	+152 +352 +327	+82 +92 +117	+184 +384 +349	+82 +92 +127	+262 +462 +427	+170 +170 +205	+320 +520 +470	+170 +170 +220	+462 +662 +627	+370 +370 +405	+520 +720 +670	+370 +370 +420	
1 800	2 000	-200	0	+152 +352 +327	+82 +92 +117	+184 +384 +349	+82 +92 +127	+262 +462 +427	+170 +170 +205	+320 +520 +470	+170 +170 +220	+482 +692 +657	+400 +400 +435	+550 +750 +700	+400 +400 +450	

Bearings application

Examples



Bearings application

Tolerance classes for housing bores

Radial bearings

Solid housing

Table 7.3

Operating conditions	Examples	Tolerance class symbol	Outer ring displacement
Rotating outer ring load			
Heavy loads on bearings in thin-walled housings, heavy shock loads ($P > 0,12C$)	Roller bearing wheel hubs, connecting rod bearing	P7	Outer ring cannot be displaced
Normal and heavy loads ($P > 0,08C$)	Ball bearing wheel hubs, connecting rod bearings, crane travelling wheels	N7	
Light and variable loads ($P \leq 0,06C$)	Conveyer rollers, rope sheaves, belt tension pulleys	M7	
Direction of load indeterminate			
Heavy shock loads	Traction motors	M7	Outer ring cannot be displaced
Normal and heavy loads ($P > 0,06C$). Outer ring displacement is not necessary	Electric motors, pumps crankshaft main bearings	K7	

Split or solid housings

Table 7.3 (continued)

Operating conditions	Examples	Tolerance class symbol	Outer ring displacement
Direction of load indeterminate			
Light and normal loads. Desirable outer ring displacement ($P \leq 0,12C$)	Medium-sized electric motors, pumps, crankshaft main bearings	J7	The outer ring can be displaced
Stationary outer ring load			
Loads of all kinds	General mechanical engineering, railway axleboxes	H7	The outer ring can be easily displaced
Light and normal loads with simple conditions ($P \leq 0,12C$)		H8	
Heat conduction through shaft	Drying cylinders, large electrical machines with spherical roller bearings	G7	

Split housings

Table 7.3 (continued)

Operating conditions	Examples	Tolerance class symbol	Outer ring displacement
High accuracy rotation, quiet running			
High shiftiness at variable loads	Main shafts for machine-tools with roller bearings	$D \leq 125$ M6 $D > 125$ N6	The outer ring cannot be displaced
Light loads, indeterminate load direction	Shaft operating surface for grinding machines with ball bearings, free bearing for high speed superchargers	K6	The outer ring cannot be displaced
Desirable outer ring displacement	Shaft operating surface for grinding machines with ball bearings, free bearing for high speed superchargers	J6	The outer ring can be displaced
Quiet running	Small-sized electrical machines	H6	The outer ring can be easily displaced

Tolerance classes for housing bores Thrust bearings

Table 7.3 (continued)

Operating conditions	Tolerance class symbol	Remarks
Axial load		
Thrust ball bearings Cylindrical and needle roller thrust bearings	H8 H7(H8)	For less accurate bearing arrangements, radial clearance in housing can be up to 0,001 D
Combined loads on spherical roller thrust bearings		
Local load on housing washer Peripheral load on housing washer	H7(H8) M7	
Axial or combined load on spherical roller thrust bearings		
Bearing radial location is ensured by another bearing	—	Housing washer fitted with clearance up to 0,001 D

Bearings application

Housing fits

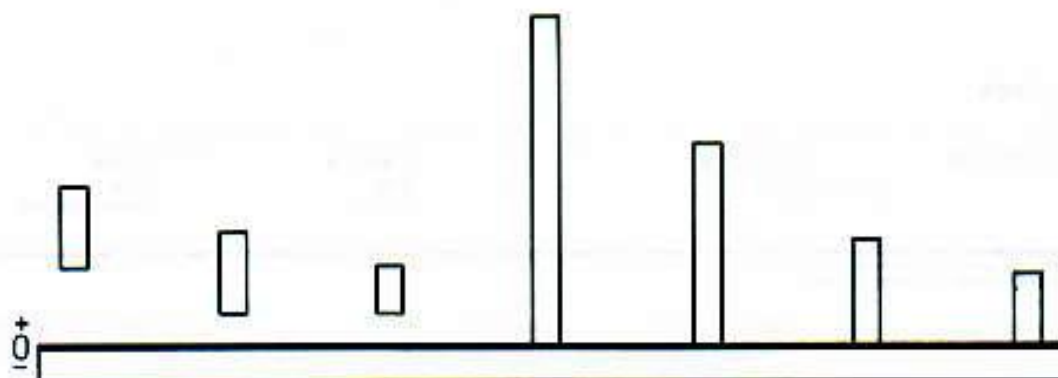


Table 7.4

Housing Diameter		Bearing Outside diameter tolerance ΔD_{mp}		Deviations of housing bore diameter, resultant fits Tolerances														
D				F7	G7	G6	H10	H9	H8	H7								
nominal				a) Deviations (housing bore diameter)														
over		up to		b) Tightening/Theoretical clearance														
		low		c) Tightening/Probable clearance														
mm		μm																
6	10	0	-8	a)	+13	+28	+5	+20	+5	+14	0	+58	0	+36	0	+22	0	+15
				b)	-13	-36	-5	-28	-5	-22	0	-86	0	-44	0	-30	0	-23
				c)	-16	-33	-8	-25	-7	-20	-3	-63	-3	-41	-3	-27	-3	-20
10	18	0	-8	a)	+16	+34	+6	+24	+8	+17	0	+70	0	+43	0	+27	0	+18
				b)	-16	-42	-6	-32	-8	-25	0	-78	0	-51	0	-35	0	-28
				c)	-19	-38	-9	-29	-8	-23	-3	-75	-3	-48	-3	-32	3	-23
18	30	0	-9	a)	+20	+41	+7	+28	+7	+20	0	+84	0	+52	0	+33	0	+21
				b)	-20	-50	-7	-37	-7	-29	0	-93	0	-61	0	-42	0	-30
				c)	-23	-47	-10	-34	-10	-28	-4	-89	-4	-57	-3	-39	-3	-27
30	50	0	-11	a)	+25	+50	-9	+34	+9	+25	0	+100	0	+62	0	+39	0	+25
				b)	-25	-61	-9	-45	-9	-38	0	-111	0	-73	0	-50	0	-36
				c)	-29	-57	-13	-41	-12	-33	-5	-106	-5	-68	-4	-46	-4	-32
50	80	0	-13	a)	+30	+60	+10	+40	+10	+28	0	+120	0	+74	0	+48	0	+30
				b)	-30	-73	-10	-53	-10	-42	0	-133	0	-87	0	-59	0	-43
				c)	-35	-88	-15	-48	-14	-38	-6	-127	-5	-82	-5	-54	-5	-38
80	120	0	-15	a)	+36	+71	+12	+47	+12	+34	0	+140	0	+87	0	+54	0	+35
				b)	-36	-86	-12	-62	-12	-49	0	-155	0	-102	0	-68	0	-50
				c)	-41	-81	-17	-57	-17	-44	-7	-148	-6	-95	-6	-63	-5	-45
120	150	0	-16	a)	+43	+83	+14	+54	+14	+39	0	+160	0	+100	0	+63	0	+40
				b)	-43	-101	-14	-72	-14	-57	0	-178	0	-118	0	-81	0	-58
				c)	-50	-94	-21	-65	-20	-51	-8	-170	-6	-110	-7	-74	-7	-51
150	180	0	-25	a)	+43	+83	+14	+54	+14	+39	0	+160	0	+100	0	+63	0	+40
				b)	-43	-108	-14	-79	-14	-64	0	-185	0	-125	0	-88	0	-65
				c)	-51	-100	-22	-71	-21	-57	-11	-174	-10	-115	-10	-78	-8	-57
180	250	0	-30	a)	+50	+98	+15	+61	+15	+44	0	+185	0	+115	0	+72	0	+48
				b)	-50	-126	-15	-81	-15	-74	0	-215	0	-145	0	-102	0	-78
				c)	-60	-118	-25	-81	-23	-66	-13	-202	-13	-132	-12	-90	-10	-68
250	315	0	-35	a)	+56	+106	-17	+69	+17	+49	0	+210	0	+130	0	+81	0	+52
				b)	-56	-143	-17	-104	-17	-84	0	-245	0	-165	0	-118	0	-87
				c)	-68	-131	-29	-92	-28	-75	-18	-229	-15	-150	-13	-103	-12	-75
315	400	0	-40	a)	+62	+119	+18	+75	+18	+54	0	+230	0	+140	0	+89	0	+57
				b)	-62	-158	-18	-115	-18	-94	0	-270	0	-180	0	-129	0	-97
				c)	-75	-148	-31	-102	-29	-83	-18	-252	-17	-163	-15	-114	-13	-84
400	500	0	-45	a)	+68	+131	+20	+83	+20	+60	0	+250	0	+155	0	+97	0	+63
				b)	-68	-178	-20	-128	-20	-105	0	-285	0	-200	0	-142	0	-108
				c)	-83	-161	-35	-113	-32	-93	-20	-275	-19	-181	-17	-125	-15	-83
500	630	0	-50	a)	+76	+146	+22	+92	+22	+68	0	+280	0	+175	0	+110	0	+70
				b)	-76	-196	-22	-142	-22	-116	0	-330	0	-225	0	-160	0	-120
				c)	-92	-180	-36	-128	-35	-103	-22	-308	-21	-204	-19	-141	-16	-104

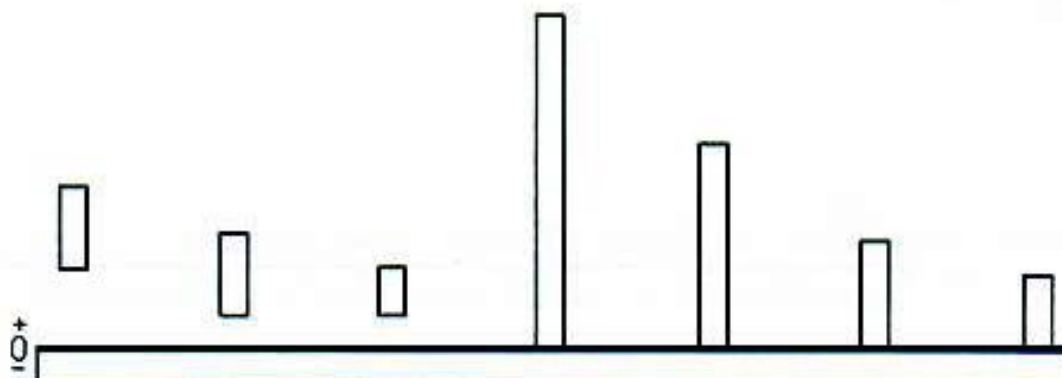


Table 7.4 (continued)

Housing Diameter		Bearing Outside diameter tolerance ΔD_{mp}		Deviations of housing bore diameter, resultant fits Tolerances													
D				F7	G7	G8	H10	H9	H8	H7							
nominal				a) Deviations (housing bore diameter)													
over	up to	low	high	b) Tightening/Theoretical clearance													
				c) Tightening/Probable clearance													
mm		μm															
630	800	0	-75	a) +80 b) -80 c) -102	+180 -235 -213	+24 -24 -46	+104 -178 -157	+24 -24 -41	+74 -149 -132	0 0 -33	+320 -395 -382	0 0 -30	+200 -275 -245	0 0 -27	+125 -200 -173	0 0 -22	+80 -155 -133
800	1 000	0	-100	+88 -88 -113	+176 -276 -249	+28 -26 -53	+118 -216 -189	+28 -26 -46	+82 -182 -162	0 0 -43	+360 -460 -417	0 0 -39	+230 -330 -291	0 0 -33	+140 -240 -207	0 0 -27	+60 -180 -169
1 000	1 250	0	-125	+98 -98 -131	+203 -328 -295	+28 -28 -61	+133 -256 -225	+28 -28 -52	+94 -218 -195	0 0 -53	+420 -545 -492	0 0 -48	+260 -385 -337	0 0 -41	+165 -280 -248	0 0 -33	+105 -230 -197
1 250	1 600	0	-160	+110 -110 -150	+235 -395 -355	+30 -30 -70	+155 -315 -275	+30 -30 -60	+108 -268 -238	0 0 -67	+500 -680 -593	0 0 -80	+310 -470 -410	0 0 -51	+195 -355 -304	0 0 -40	+125 -265 -245
1 600	2 000	0	-200	+120 -120 -170	+270 -470 -420	+32 -32 -62	+182 -382 -332	+32 -32 -67	+124 -324 -289	0 0 -83	+600 -800 -717	0 0 -74	+370 -570 -496	0 0 -62	+230 -430 -388	0 0 -50	+150 -350 -300
2 000	2 500	0	-250	+130 -130 -189	+305 -555 -496	+34 -34 -83	+209 -459 -400	+34 -34 -77	+144 -384 -351	0 0 -103	+700 -950 -847	0 0 -91	+440 -690 -598	0 0 -77	+280 -530 -453	0 0 -56	+175 -425 -366

Bearings application Housing fits

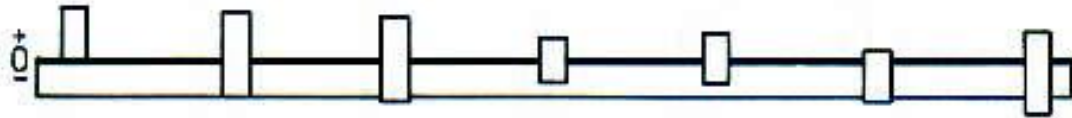


Table 7.4 (continued)

Housing Diameter		Bearing Outside diameter tolerance ΔD_{mp}		Deviations of housing bore diameter, resultant fits Tolerances													
D				H6	J7	J57	J6	J56	K6	K7							
nominal				a) Deviations (housing bore diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance													
over	up to	low	high														
mm		μm															
6	10	0	-8	a) 0 b) 0 c) -2	+9 -17 -15	-7 +7 +4	+8 -18 -13	-7,5 +7,5 +5	+7,5 -15,5 -13	-4 +4 +2	+5 -13 -11	-4,5 +4,5 +3	+4,5 -12,5 -11	-7 +7 +5	+2 -10 -8	-10 +10 +7	+5 -13 -10
10	18	0	-8	0 0 -2	+11 -18 -17	-8 +8 +5	+10 -18 -15	-9 +9 +6	+9 -17 -14	-5 +5 +3	+6 -14 -12	-5,5 +5,5 +3	+5,5 -13,5 -11	-8 +9 +7	+2 -10 -8	-12 +12 +9	+8 -14 -11
18	30	0	-9	0 0 -3	+13 -22 -19	-9 +9 +6	+12 -21 -18	-10,5 +10,5 +7	+10,5 -18,5 -16	-5 +5 +2	+8 -17 -14	-6,5 +6,5 +4	+6,5 -15,5 -13	-11 +11 +8	+2 -11 -8	-15 +15 +12	+8 -15 -12
30	50	0	-11	0 0 -3	+18 -27 -24	-11 +11 +7	+14 -25 -21	-12,5 +12,5 +9	+12,5 -23,5 -20	-8 +8 +3	+10 -21 -18	-8 +8 +5	+8 -19 -16	-13 +13 +10	+3 -14 -11	-18 +18 +14	+7 -18 -14
50	80	0	-13	0 0 -4	+19 -32 -28	-12 +12 +7	+18 -31 -26	-15 +15 +10	+15 -28 -23	-8 +8 +2	+13 -26 -22	-8,5 +9,5 +8	+9,5 -22,5 -19	-15 +15 +11	+4 -17 -13	-21 +21 +16	+9 -22 -17
80	120	0	-15	0 0 -5	+22 -37 -32	-13 +13 +8	+22 -37 -32	-17,5 +17,5 +12	+17,5 -32,5 -27	-8 +8 +1	+16 -31 -26	-11 +11 +8	+11 -26 -21	-18 +18 +13	+4 -19 -14	-25 +25 +20	+10 -25 -20
120	150	0	-18	0 0 -6	+25 -43 -37	-14 +14 +7	+26 -44 -37	-20 +20 +13	+20 -38 -31	-7 +7 +1	+18 -38 -30	-12,5 +12,5 +7	+12,5 -30,5 -25	-21 +21 +15	+4 -22 -16	-28 +28 +21	+12 -30 -23
150	180	0	-25	0 0 -7	+25 -50 -43	-14 +14 +6	+26 -51 -43	-20 +20 +12	+20 -45 -37	-7 +7 0	+18 -43 -36	-12,5 +12,5 +6	+12,5 -37,5 -31	-21 +21 +14	+4 -29 -22	-28 +28 +20	+12 -37 -29
180	250	0	-30	0 0 -8	+29 -59 -51	-16 +18 +6	+30 -60 -50	-23 +23 +13	+23 -53 -43	-7 +7 -1	+22 -52 -44	-14,5 +14,5 +6	+14,5 -44,5 -36	-24 +24 +16	+5 -35 -27	-33 +33 +23	+13 -43 -33
250	315	0	-35	0 0 -9	+32 -67 -58	-18 +18 +4	+36 -71 -59	-26 +26 +14	+26 -61 -48	-7 +7 -2	+25 -60 -51	-16 +18 +7	+18 -51 -42	-27 +27 +18	+5 -40 -31	-38 +38 +24	+16 -51 -39
315	400	0	-40	0 0 -11	+38 -78 -65	-18 +18 +5	+39 -79 -66	-28,5 +28,5 +15	+28,5 -68,5 -55	-7 +7 -4	+29 -68 -56	-18 +18 +7	+18 -58 -47	-29 +29 +18	+7 -47 -36	-40 +40 +27	+17 -57 -44
400	500	0	-45	0 0 -12	+40 -85 -73	-20 +20 +5	+43 -86 -73	-31,5 +31,5 +17	+31,5 -78,5 -62	-7 +7 -5	+33 -78 -66	-20 +20 +8	+20 -65 -53	-32 +32 +20	+8 -53 -41	-45 +45 +30	+18 -83 -46
500	630	0	-50	0 0 -13	+44 -94 -81	-	-	-35 +35 +18	+35 -85 -69	-	-	-22 +22 +9	+22 -72 -59	-44 +44 +31	0 -50 -37	-70 +70 +54	0 -50 -34

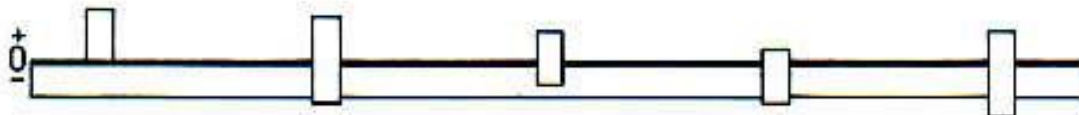


Table 7.4 (continued)

Housing Diameter		Bearing Outside diameter tolerance ΔD_{mp}		Deviations of housing bore diameter, resultant fits Tolerances									
D				H6	JS7		JS6		K6		K7		
nominal				a) Deviations (housing bore diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance									
over	up to	low	high										
mm		μm											
630	800	0	-75	a) 0 b) 0 c) -17	+50 -125 -108	-40 +40 +18	+40 -115 -93	-25 +25 +8	+25 -100 -83	-60 +50 +33	0 -75 -58	-80 +80 +58	0 -75 -53
800	1 000	0	-100	0 0 -20	+56 -158 -138	-45 +45 +18	+45 -145 -118	-28 +28 +8	+28 -128 -108	-58 +58 +38	0 -100 -80	-90 +90 +63	0 -100 -73
1 000	1 250	0	-125	0 0 -24	+66 -181 -187	-52 +52 +20	+52 -177 -145	-33 +33 +8	+33 -158 -134	-88 +68 +42	0 -125 -101	-105 +105 +72	0 -125 -92
1 250	1 800	0	-160	0 0 -30	+78 -238 -208	-62 +62 +22	+62 -222 -182	-39 +39 +8	+39 -199 -168	-78 +78 +48	0 -160 -130	-125 +125 +85	0 -160 -120
1 800	2 000	0	-200	0 0 -35	+82 -292 -257	-75 +75 +25	+75 -275 -225	-48 +48 +11	+48 -248 -211	-92 +92 +57	0 -200 -165	-150 +150 +100	0 -200 -150
2 000	2 500	0	-250	0 0 -43	+110 -360 -317	-87 +87 +28	+87 -337 -278	-55 +55 +12	+55 -305 -262	-110 +110 +67	0 -250 -207	-175 +175 +118	0 -250 -191

Bearings application

Housing fits

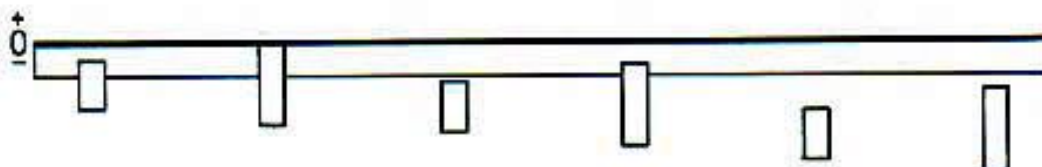


Table 7.4 (continued)

Housing Diameter		Bearing Outside diameter tolerance ΔD_{mp}		Deviations of housing bore diameter, resultant fits Tolerances																							
D				M6		M7		N6		N7		P6		P7													
nominal																											
over	up to	low	high	a) Deviations (housing bore diameter) b) Tightening/Theoretical clearance c) Tightening/Probable clearance																							
mm		μm																									
6	10	0	-8	a) -12 b) +12 c) +10	-3 -5 -3	-15 +15 +12	0 -8 -5	-16 +16 +14	-7 -1 +1	-19 +19 +18	-4 -4 -1	-21 +21 +18	-12 +4 +6	-24 +24 +21	-8 +1 +4												
10	18	0	-8	-15 +15 +13	-4 -4 -2	-18 +18 +15	0 -8 -5	-20 +20 +18	-9 +1 +3	-23 +23 +20	-5 -3 0	-26 +26 +24	-15 +7 +9	-29 +29 +28	-11 +3 +8												
18	30	0	-9	-17 +17 +14	-4 -5 -2	-21 +21 +18	0 -9 -8	-24 +24 +21	-11 +2 +5	-28 +28 +25	-7 -2 +1	-31 +31 +28	-18 +9 +12	-35 +35 +32	-14 +5 +8												
30	50	0	-11	-20 +20 +17	-4 -7 -4	-25 +25 +21	0 -11 -7	-28 +28 +25	-12 +1 +4	-33 +33 +29	-8 -3 +1	-37 +37 +34	-21 +10 +13	-42 +42 +38	-17 +6 +10												
50	80	0	-13	-24 +24 +20	-6 -8 -4	-30 +30 +25	0 -13 -8	-33 +33 +29	-14 +1 +5	-39 +39 +34	-9 -4 +1	-45 +45 +41	-28 +13 +17	-51 +51 +46	-21 +8 +13												
80	120	0	-15	-28 +28 +23	-8 -9 -4	-35 +35 +30	0 -15 -10	-38 +38 +33	-16 +1 +8	-45 +45 +40	-10 -5 0	-52 +52 +47	-30 +15 +20	-59 +59 +54	-24 +9 +14												
120	150	0	-18	-33 +33 +27	-8 -10 -4	-40 +40 +33	0 -18 -11	-45 +45 +39	-20 +2 +8	-52 +52 +45	-12 -8 +1	-61 +61 +55	-38 +18 +24	-68 +68 +61	-28 +10 +17												
150	180	0	-25	-33 +33 +26	-8 -17 -10	-40 +40 +32	0 -25 -17	-45 +45 +38	-20 -5 +2	-52 +52 +44	-12 -13 -5	-61 +61 +54	-38 +11 +18	-68 +68 +60	-28 +3 +11												
180	250	0	-30	-37 +37 +28	-8 -22 -14	-46 +46 +38	0 -30 -20	-51 +51 +43	-22 -8 0	-60 +60 +50	-14 -16 -8	-70 +70 +62	-41 +11 +19	-79 +79 +69	-33 +3 +13												
250	315	0	-35	-41 +41 +32	-9 -26 -17	-52 +52 +40	0 -35 -23	-57 +57 +48	-25 -10 -1	-68 +68 +54	-14 -21 -8	-79 +79 +70	-47 +12 +21	-88 +88 +76	-38 +1 +13												
315	400	0	-40	-46 +46 +35	-10 -30 -19	-57 +57 +44	0 -40 -27	-62 +62 +51	-26 -14 -3	-73 +73 +60	-16 -24 -11	-87 +87 +76	-51 +11 +22	-98 +98 +85	-41 +1 +14												
400	500	0	-45	-50 +50 +38	-10 -35 -23	-63 +63 +48	0 -45 -30	-67 +67 +55	-27 -18 -6	-80 +80 +65	-17 -26 -13	-95 +95 +83	-55 +10 +22	-108 +108 +83	-45 0 +15												
500	630	0	-50	-70 +70 +57	-26 -24 -11	-88 +88 +80	-26 -24 -8	-88 +88 +75	-44 -8 +7	-114 +114 +98	-44 -6 +10	-122 +122 +109	-78 +28 +41	-148 +148 +132	-78 +28 +44												

=2070 c

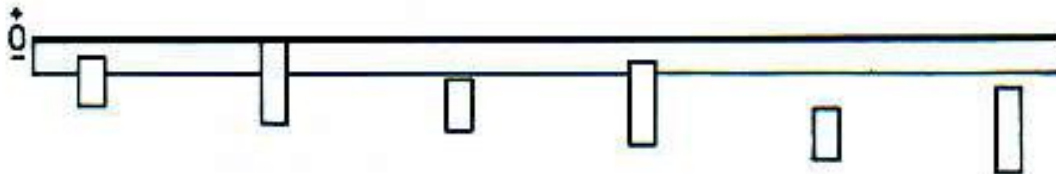


Table 7.4 (continued)

Housing Diameter		Bearing Outside diameter tolerance ΔD_{mp}		Deviations of housing bore diameter, resultant fits Tolerances											
D				M6	M7	N6	N7	P6	P7						
nominal				a) Deviations (housing bore diameter)											
over	up to	low	high	b) Tightening/Theoretical clearance											
				c) Tightening/Probable clearance											
mm		μm													
630	800	0	-75	a) -80 b) +80 c) +83	-30 -45 -28	-110 +110 +88	-30 -45 -23	-100 +100 +63	-50 -25 -8	-130 +130 +108	-30 -25 -3	-138 +138 +121	-88 +13 +30	-168 +168 +146	-88 +13 +35
800	1 000	0	-100	-80 +80 +70	-34 -68 -46	-124 +124 +97	-34 -66 -39	-112 +112 +82	-58 -44 -24	-148 +148 +119	-58 -44 -17	-158 +158 +136	-100 0 +20	-180 +180 +163	-100 0 +27
1 000	1 250	0	-125	-108 +108 +82	-40 -85 -61	-145 +145 +112	-40 -85 -52	-132 +132 +108	-66 -59 -35	-171 +171 +138	-66 -59 -26	-186 +188 +182	-120 -5 +19	-225 +225 +192	-120 -5 +26
1 250	1 600	0	-160	-128 +128 +98	-48 -112 -82	-173 +173 +133	-48 -112 -72	-158 +158 +128	-78 -82 -52	-203 +203 +163	-78 -82 -42	-218 +218 +188	-140 -20 +10	-285 +265 +225	-140 -20 +20
1 600	2 000	0	-200	-150 +150 +115	-58 -142 -107	-208 +208 +158	-58 -142 -92	-184 +184 +148	-92 -108 -73	-242 +242 +192	-92 -108 -58	-262 +262 +227	-170 -30 +5	-320 +320 +270	-170 -30 +20
2 000	2 500	0	-250	-178 +178 +135	-68 -182 -138	-243 +243 +184	-68 -182 -123	-220 +220 +177	-110 -140 -97	-285 +285 +226	-110 -140 -81	-305 +305 +262	-195 -55 -12	-370 +370 +311	-195 -55 +4

Deviations of form and position

Permissible deviations of form and position for shaft and housing where bearings are to be mounted are given in fig. 7.3 and table 7.5.

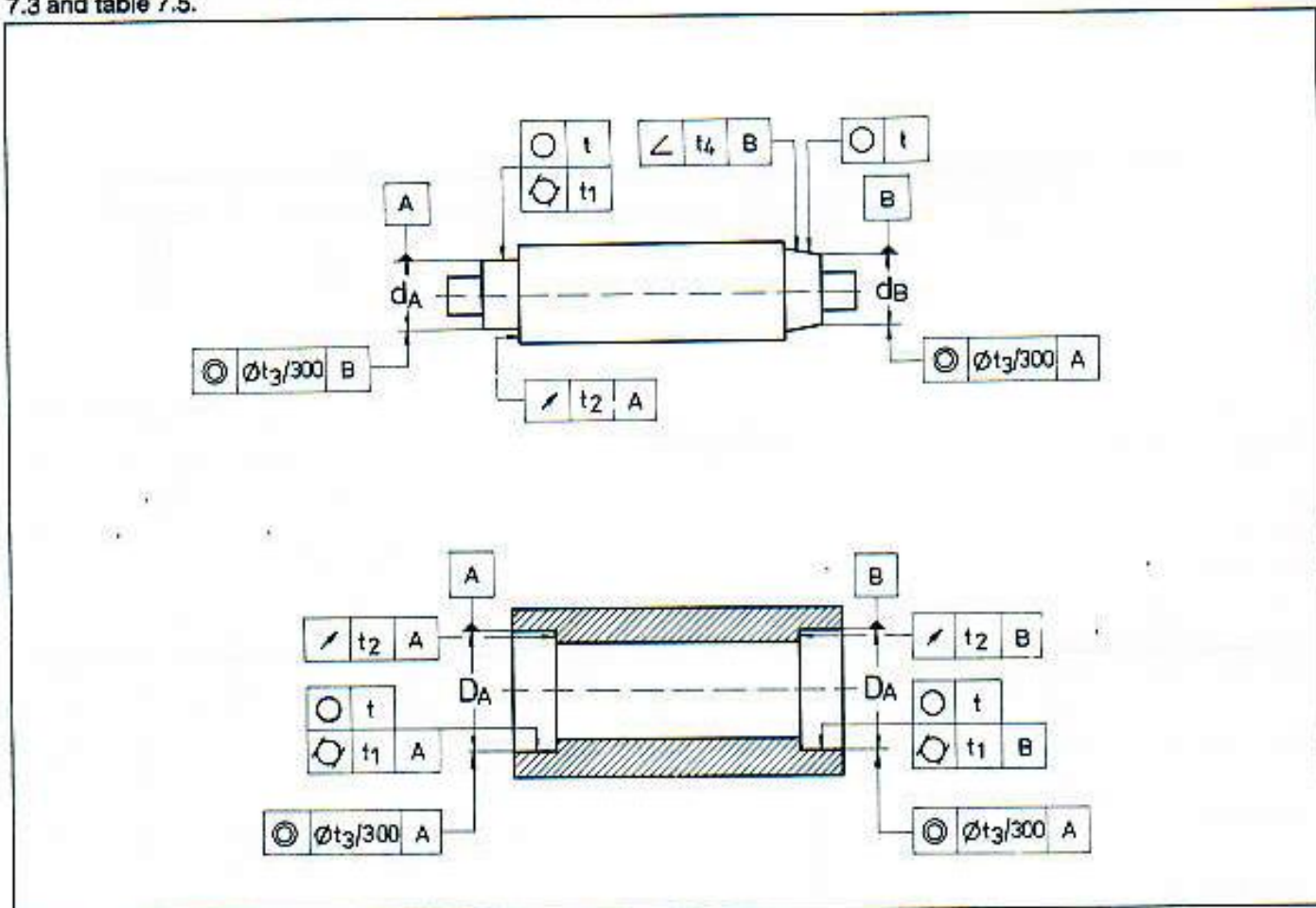


Fig.7.3.

Permissible deviations depending on the tolerance class

Table 7.5

Tolerance name	Fit	Symbol of deviation		Permissible deviations depending on the tolerance class				
				P0 P6X	P6	P5	P4(SP)	P2(UP)
Tolerance of dimension	shaft housing	-	-	IT8(IT5) IT7(IT6)	IT5 IT6	IT4 IT5	IT4 IT4	IT3 IT4
Tolerance of roundness and cylindricity	shaft		t_1	$\frac{IT4}{2} \left(\frac{IT3}{2} \right)$	$\frac{IT3}{2} \left(\frac{IT2}{2} \right)$	$\frac{IT2}{2}$	$\frac{IT1}{2}$	$\frac{IT0}{2}$
	housing		t_1	$\frac{IT5}{2} \left(\frac{IT4}{2} \right)$	$\frac{IT4}{2} \left(\frac{IT2}{2} \right)$	$\frac{IT3}{2}$	$\frac{IT2}{2}$	$\frac{IT1}{2}$
Tolerance of face runout	shaft housing		t_2	IT4(IT3) IT5(IT4)	IT3(IT2) IT4(IT3)	IT2 IT3	IT1 IT2	IT0 IT1
Tolerance of concentricity	shaft housing		t_3	IT5 IT6	IT4 IT5	IT4 IT5	IT3 IT4	IT3 IT3
Tolerance of angularity	shaft		t_4	$\frac{IT7}{2}$	$\frac{IT6}{2}$	$\frac{IT4}{2}$	$\frac{IT3}{2}$	$\frac{IT2}{2}$

In case of bearings on which adapter or withdrawal sleeves are to be mounted, the shaft tolerances for deviations of form and position should be to IT 5/2 tolerance class for shafts with diameter tolerance h9 and IT7/2 for

shaft tolerance h10.

Surface roughness of bearing seating is given in table 7.6.

Shaft and housing mounting surfaces roughness

Table 7.6

Bearing tolerance class	Shaft			Housing		
	Diameter d, mm			Diameter D, mm		
	≤ 80	> 80..500	> 500	≤ 80	> 80..500	> 500
	Roughness Ra, μm					
P0, P6X and P6	0,8 (N6)	1,8 (N7)	3,2 (N8)	0,8 (N6)	1,8 (N7)	3,2 (N8)
P5, SP and P4	0,4 (N5)	0,8 (N6)	1,8 (N7)	0,8 (N6)	1,8 (N7)	1,8 (N7)
P2 and UP	0,2 (N4)	0,4 (N5)	0,8 (N6)	0,4 (N5)	0,8 (N6)	0,8 (N6)

If bearings are mounted with adapter or withdrawal sleeves, shaft surface roughness should be of max. $R_a = 1,6 \mu m$.

The values of fundamental tolerances - ISO (tolerance classes IT0...IT12) are given in table 7.7.

Tolerance ISO (IT)

Table 7.7

Nominal dimension, mm														Table 7.7									
over up to	1 3	3 6	6 10	10 18	18 30	30 50	50 80	80 120	120 180	180 250	250 315	315 400	400 500	500 630	630 800	800 1 000	1 000 1 250	1 250 1 600	1 600 2 000	2 000 2 500	2 500 3 150		
Tolerances in micrometers (0,001 mm)																							
IT0	0,5	0,6	0,6	0,8	1	1	1,2	1,5	2	3	4	5	6										
IT1	0,8	1	1	1,2	1,5	1,5	2	2,5	3,5	4,5	6	7	8										
IT2	1,2	1,5	1,5	2	2,5	2,5	3	4	5	7	8	9	10										
IT3	2	2,5	2,5	3	4	4	5	8	8	10	12	13	15										
IT4	3	4	4	5	6	7	8	10	12	14	16	18	20										
IT5	4	5	8	8	9	11	13	15	18	20	23	25	27	29	32	36	42	50	60	70	88		
IT6	8	8	9	11	13	16	18	22	25	29	32	36	40	44	50	56	66	78	92	110	135		
IT7	10	12	15	18	21	25	30	35	40	46	52	57	63	70	80	90	105	125	150	175	210		
IT8	14	18	22	27	33	39	46	54	63	72	81	89	97	110	125	140	165	195	230	280	330		
IT9	25	30	36	43	52	62	74	87	100	115	130	140	155	175	200	230	280	310	370	440	540		
IT10	40	48	58	70	84	100	120	140	160	185	210	230	250	280	320	360	420	500	600	700	860		
IT11	80	75	90	110	130	160	190	220	250	290	320	360	400	440	500	560	660	780	920	1 100	1 350		
IT12	100	120	150	180	210	250	300	350	400	460	520	570	630	700	800	900	1 050	1 250	1 500	1 750	2 100		

Bearing axial location

Axial location of bearings is necessary for a proper guiding of bearing in an assembly under operation.

An tight fit is inadequate for the axial location of bearing. In case of locating bearings, axial location for both rings is generally needed. Some important solutions of bearing axial location, on shaft or into the housing are shown in Fig.7.4.

In case of bearings with light axial loads, bearings can be located using a lock nut and a lock washer (a), an end plate fastened by a screw at the shaft end (b) and, for bearings carrying light axial loads, by lock rings mounted in shaft and housing grooves (c).

Bearings with NR design, with groove and snap ring on the outer ring can be easily located by the lock ring (d). Tapered roller bearings can be located by supporting the inner ring on the shaft shoulder and the outer ring with a threaded ring and a safety plate fastened by a screw (e).

Tapered bore bearings can be mounted and axially located by adapter or withdrawal sleeves (f, g, h).

The axial load carrying capacity of the bearings mounted with adapter or withdrawal sleeves is governed by the friction between shaft and sleeve (g).

To locate radial bearings, where axial adjustment of the shaft is required, setting washers (i) or spacer rings (j) are used between the outer rings, the width of the spacer ring being experimentally determined, during mounting.

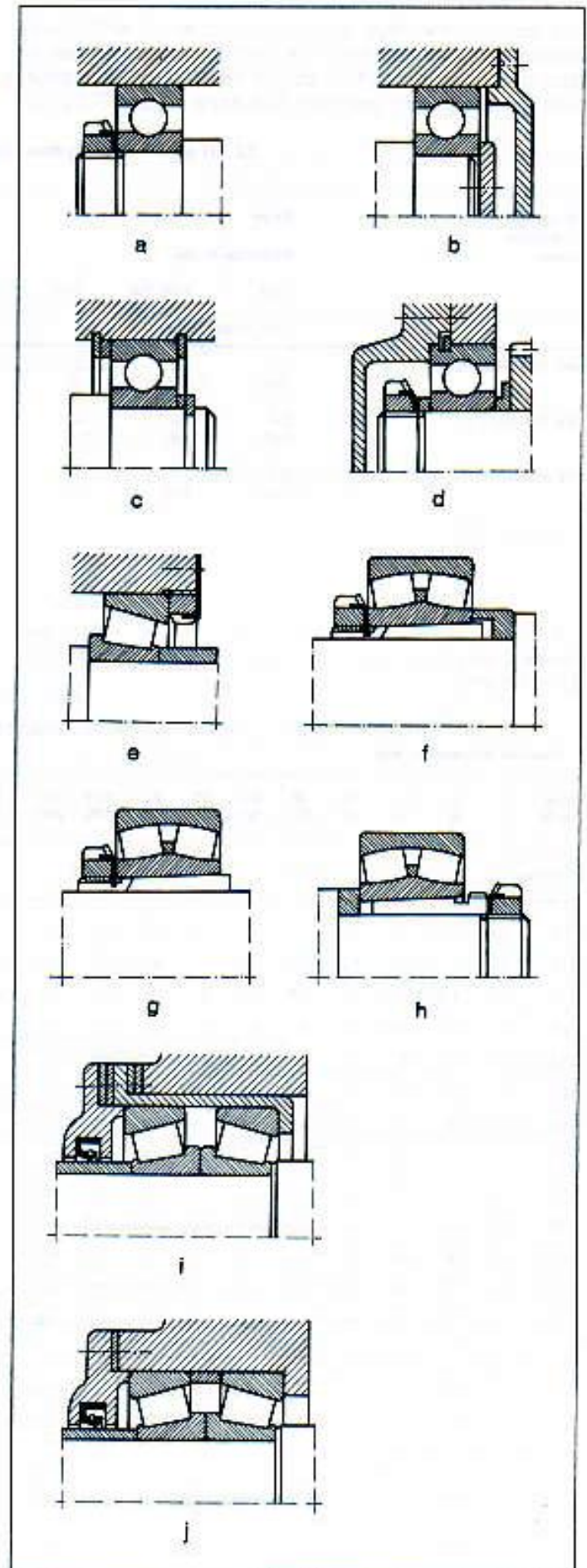


Fig. 7.4

Bearing sealing

Seals are used in most of bearing arrangements and they must ensure the conditions of a proper operation.

For such a purpose, they have to prevent solid contaminants (dust, hard particles, water, aggressive substances etc.) from penetrating into the bearing and at the same time to retain the lubricant in the bearing.

Seals for rolling bearings can be classified considering some important criteria such as: design, operation, type of lubricant etc.

Considering their design and operation, seals can be: stationary seals between the stationary bearing elements (housing and cover), rotary seals, between the rotating bearing elements and they also can be rubbing seals or non-rubbing seals, which are used in special applications (surroundings conditions and loading stress).

Rotary non-rubbing seals are often used due to their simple design. They are particularly used at high speeds or temperatures, both for grease and oil, and have practically no friction and do not wear.

In case of bearing grease lubrication, bearing operating temperature must be lower with 20°C than the dropping point of the grease (melting temperature).

The main constructive types of rotary non-rubbing seals have narrow gaps, labyrinths and their combinations are shown in fig. 7.5 a-c.

Gap seals represent the simplest constructive solution for a rotary non-rubbing seal which have to retain grease in the bearing housing. The efficacy of sealing depends on the gap length (L) and the clearance between shaft and housing. It can be improved by providing one or more circular grooves on the shaft or in the housing, which are to be filled with grease (b). In case of oil lubrication, the grooves on the shaft must be helical (c) and their direction must be the same with the direction of the shaft rotary movement.

Experiments proved that most favorable clearance is obtained between the limits of the fit A11/h10, geometrical deviations should be IT6 and gap surface roughness $R_a = 12,6\mu\text{m}$.

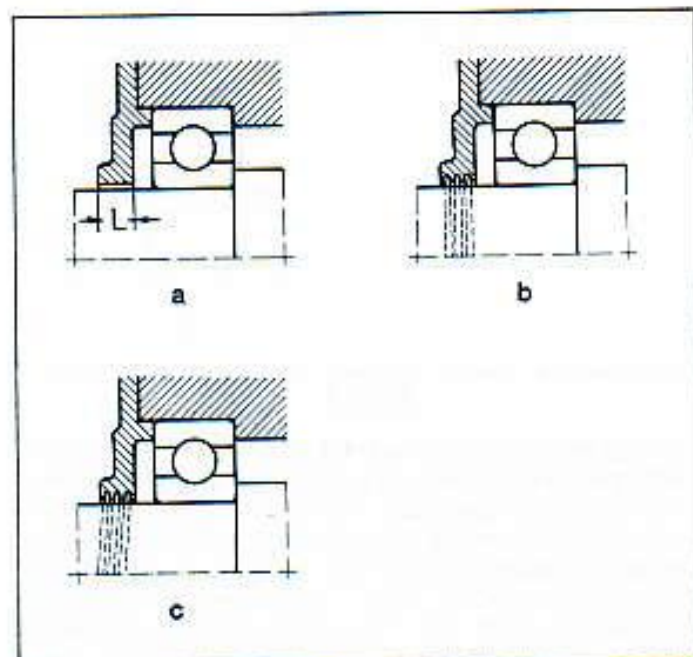


Fig. 7.5

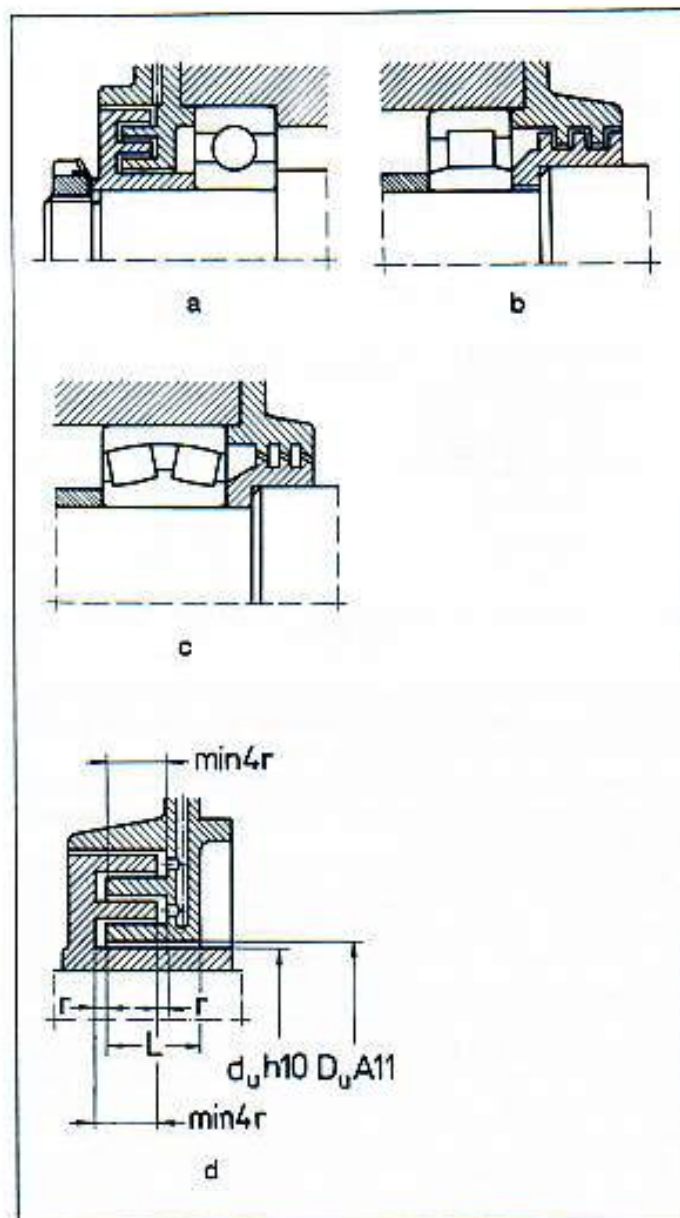


Fig. 7.6

Labyrinth seals are used at high peripheral speeds, in impure surroundings. They are shown in fig. 7.6 a-d.

The labyrinths are spaces where periodically water-insoluble grease (e.g. Lithium or Calcium base grease) is to be supplied.

The tongues of the labyrinth seals can be radially (a), axially (b) arranged or they can have inclined passages.

Details of an axial labyrinth design are given in fig. 7.6 d and values of axial clearance r and length L are given in table 7.8.

Values for dimensions r and L

Table 7.8

d		Axial clearance r	Length L
over	up to		
mm			
—	50	1,5	13,5...27
50	120	2	18...38
120	160	2,5	22,5...45

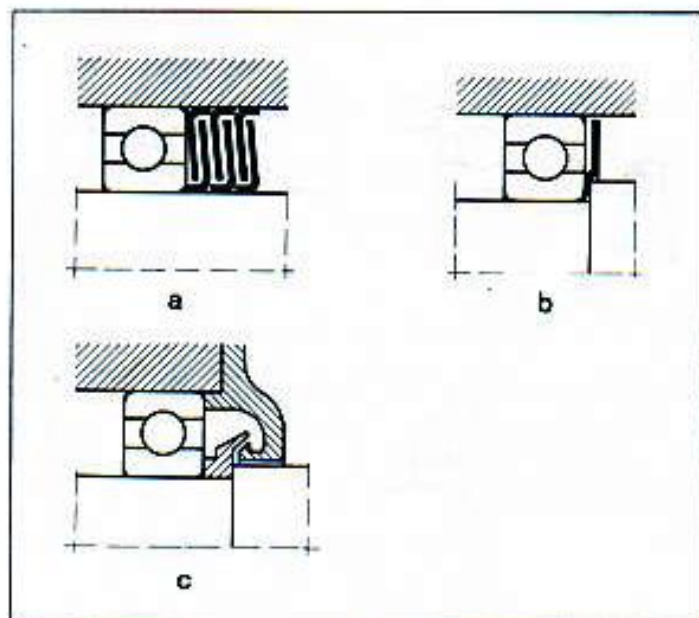


Fig. 7.7

Sealing efficacy increases where both radial and axial labyrinths are used and the number of gaps is increased.

Other types of seals are shown in fig. 7.7 a-c.

In case of rotary rubbing seals there is a direct contact between a seal elastic element and the rotating element. They are shown in fig. 7.8.

When selecting the proper rotary rubbing seal, the following factors have to be considered: material and its elasticity (felt, rubber, plastics, leather, graphite, asbestos etc.); resistance at various temperatures, maximum peripheral speed on sealing surface; sealing direction etc. These systems have sealing properties higher than those corresponding to non-rubbing seals. In case of grease lubrication at peripheral speeds higher than 4 m/s and temperatures over $+100^{\circ}\text{C}$, felt ring seals (a) are frequently used because of their simple design and cheapness.

Before mounting, felt rings are impregnated during an hour with a mixture of mineral oil (66%) and paraffin (34%), at a temperature of $+70^{\circ}\text{C}$ to $+80^{\circ}\text{C}$ so that sealing properties are improved as the friction is reduced.

At higher temperatures and peripheral speeds over 12 m/s, surface roughness is $R_a = 1,6 \mu\text{m}$ and the space between the ends of the seal should be filled with grease. Two felt rings can be used for sealing.

Rubbing seals with a spring incorporated are preferably to be used in case of oil lubricated bearings which are operated under peripheral speeds of 5-10 m/s, temperatures between -40°C and $+20^{\circ}\text{C}$. Their efficacy depends on the material and operating surroundings.

In most cases, rubbing seals with a spring incorporated are made of synthetic rubber and have a metallic hardening fixture.

Inclined sealing surfaces are recommended to be ground at $R_a = 0,8 \mu\text{m}$ and hardened at 45 HRC, when operating at peripheral speeds over 8 m/s. Lubricant outflow can be stopped by mounting the rubbing seal with incorporated spring with the edge inwards (c) or outwards (d) if sealing has to prevent dust or other impurities from penetrating into the bearing.

Double sealing with these rubbing seals can also be used.

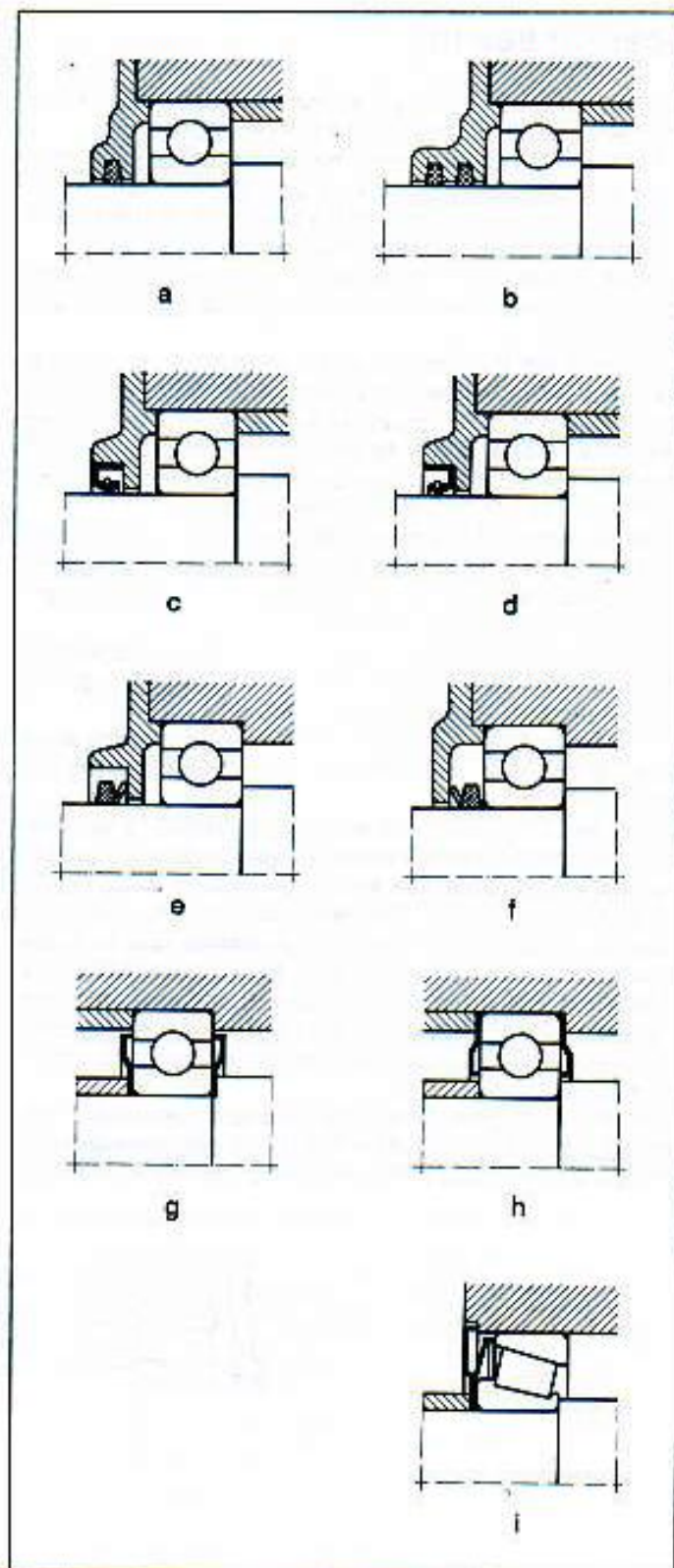


Fig. 7.8

V-ring seal is used to prevent dust or contaminants from penetrating into the bearing with best results both in case of grease or oil lubrication. The elastic rubber lip of the V-ring seal is notched on the plane sealing surface, drawing the fluids in centrifugal motion. V-ring seals are used at temperatures of -40°C to $+100^{\circ}\text{C}$, roughness of sealing surface being $R_a = 1,5 - 3 \mu\text{m}$. Generally, at peripheral speeds up to 15 m/s, the V-ring seal operates as a rubbing seal.

(seal lip reaches sealing surface), and at peripheral speeds over 15 m/s the seal lip will lift from the sealing surface, operating as a centrifugal sealing.

V-ring seals can also be used in case of angular misalignments of the shaft ($2^\circ \dots 3^\circ$), as they are made of high quality, elastic rubber, easy to be mounted.

The efficacy of sealing depends on the fact that the ring body acts as a flinger for dirt and fluids. Therefore, with grease lubrication the seal is generally arranged outside the housing and with oil lubrication it is placed inside the housing.

Pressed sheet washers provide simple, inexpensive and space-saving sealing especially for grease lubricated deep groove ball bearings. The washers are clamped against either the outer ring or the inner ring and exert a resilient pressure axially against the rubbing ring. For tapered roller bearings, two elastic washers are usually used, the space between them being filled with grease.

In case of usual applications, the types of seals mentioned above or their combinations shown in fig. 7.9 are used, some of them becoming standard seals for rolling bearings (e.g. labyrinths, felt rings, V-rings etc.). Thus, better sealing can be obtained if felt ring (a) or V-ring (b) rubbing seals are combined with radial or axial labyrinth non-rubbing seals.

Special seals are used in case of unusual surroundings and loading conditions (e.g. rolling mills, helm of ocean-vessels, main shaft of grinding machines etc.)

Sealed bearings of the type 2RS (2RSR) (a) or shielded bearings of the type 2Z (2ZR) (b) shown in fig. 7.10 a.b. provide simple and inexpensive sealing, with upper operating results. These rolling bearings are delivered ready greased, provision for relubrication and maintenance are not needed. They are used in case of bearings with small free space where other seals cannot be used.

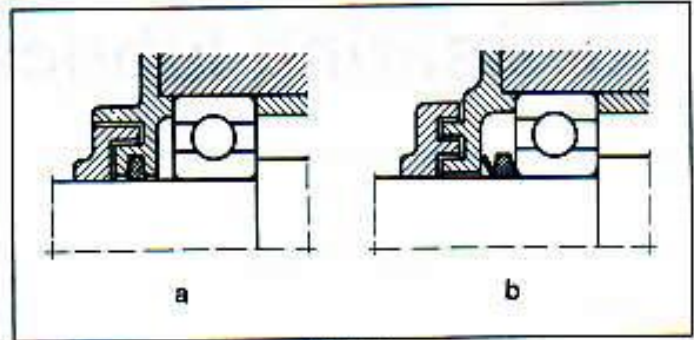


Fig. 7.9

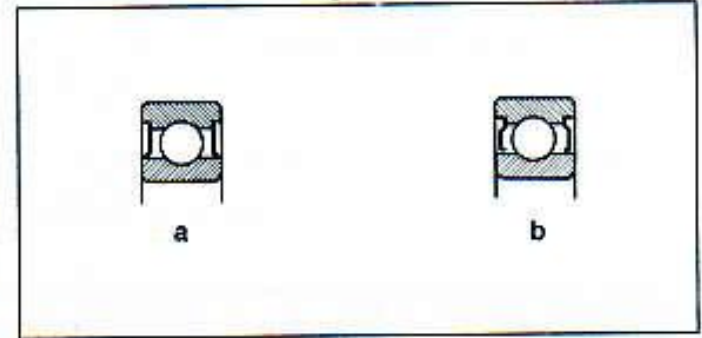


Fig. 7.10